A Summary of Current Program, 4/1/66

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and Preliminary Report of Progress

for 4/1/65 to 3/31/66

AGRICULTURAL ENGINEERING RESEARCH DIVISION

of the

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

and related work of the

STATE AGRICULTURAL EXPERIMENT STATIONS

This progress report of USDA and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on USDA and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of USDA and cooperative research issued between April 1, 1965, and March 31, 1966. Current agricultural research findings are also published in the monthly USDA publication, Agricultural Research. This progress report was compiled in the Agricultural Engineering Research Division, Agricultural Research Service, U.S. Department of Agriculture, Plant Industry Station, Beltsville, Maryland.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.
September 15, 1966

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INTRODUCTION

Agricultural Engineering Research as used in this report is concerned with the applications of engineering principles to agricultural production and rural living. More specifically, it deals with the power, machines and structures required, and includes (a) development of new and improved equipment for the more effective mechanization of seedbed preparation, fertilization, planting, cultivation, pesticide application, harvesting and farm handling of crops, and studies of the more efficient use of such equipment; (b) development of more effective and lower cost buildings and equipment for the handling and sheltering of livestock, including research in functional requirements, for the handling and storing of farm commodities on the farm, and for farm living; (c) development of more effective methods and equipment for the mechanical preparation and conditioning of farm products for farm use or sale, including such testing and quality determination as needed to adequately evaluate research results, and (d) adaptation and development of methods and equipment for effective and economical farm and rural applications of electric energy, used as power, heat, light and other electromagnetic radiations for plant and animal production, farm processing and rural living.

The importance of Agricultural Engineering research to the nation's agriculture is shown by the fact that power, machines and structures with which it is concerned are essential facilities for every one of the approximately more than 3-1/4 million farms. Also, the solutions of most plant and animal production problems are in part determined by the machines and structures available and likewise almost every new finding in soil, plant or animal science research requires additional engineering research for its most effective implementation. As the relative cost of labor increases and the mechanization of agricultural operations progresses, engineering research becomes increasingly important. Since the close of World War II the annual man-hours of farm labor have been reduced by 55 percent, from 18.8 billion to 7.9 billion, the number of tractors has doubled, from about 2.4 million to 4.6 million, and the percent of farms served by electric power lines has also doubled from about 48 to over 98. Each farm worker has available between 30 and 40 mechanical and electric horsepower. The investment per worker for land and other facilities, which is higher than for all manufacturing, averages over $30,000. For many commercial farms it is more than twice as great and for certain types of farms over large areas it is $100,000 or more.

However, in spite of the rapid and unprecedented progress in farm mechanization during recent years, many important field and farmstead operations are still not mechanized or are only inadequately mechanized. There are also many unsolved problems in the mechanical preparation and conditioning of farm products for farm storage and use, and for sale. There are many undeveloped opportunities for the more effective and extensive application of the different forms of electromagnetic energy and there is urgent need for the development of more effective and economic farm buildings for storing products, sheltering livestock, and farm family living.

Agricultural Engineering research is carried out by the Agricultural Engineering Research Division of the Agricultural Research Service of the U. S. Department of Agriculture, by nearly all of the State Experiment Stations, and by farm equipment manufacturers, manufacturers of building materials and prefabricated buildings, and to a limited extent by trade associations.

A characteristic of current Agricultural Engineering research is the relatively small program of the USDA and also of the State Experiment Stations in this field compared to that of public research in other fields of agriculture. This imbalance is serious because 80 percent or more of all agricultural research involves engineering, either during its conduct or during the application of its positive findings. Also as agriculture becomes more complex the need for expanded public agency research in agricultural engineering to determine for industry the fundamental principles and the basic requirements of the power, machinery and structures needed for an efficient agriculture become increasingly urgent.

In commenting on Balance among Phases of the U.S.D.A. Research Program in its report of April, 1965, the National Agricultural Research Advisory Committee stated, "Problems in agricultural research are constantly changing in relative importance necessitating a periodic review to maintain a proper balance. ----------
It believes the current level of engineering research both on the part of the USDA and the State Experiment Stations is too low."

Thus, although there is need for the expansion of independent basic research in agricultural engineering, there is also need for a considerable expansion of agricultural engineering research cooperative and concurrent with other related agricultural research programs and also cooperative with industry whenever circumstances indicate the desirability of such co-operation. It should be noted that public agency research in agricultural engineering is complementary to and often cooperative with private research and not a competitive duplication of research by industry.

The Agricultural Engineering Research Division has 36 of its 170 professional workers located at the Beltsville Agricultural Research Center; 47 at 16 federal field stations, and 87 at 33 State Experiment Stations.

Of the 87 Department professional workers now at State Station locations, 33 are in 8 specialized federal laboratories, such as the National Tillage Machinery Laboratory at Auburn, Ala. Most are working cooperatively with State-employed workers on mutually agreed problems that have both State and National significance. Much of the research is carried on by teams including both engineers and scientists trained in other disciplines.

The program at Beltsville includes leadership for work done in the field and research on problems of National interest. Basic research, involving about 44 engineers, conducted at 24 locations, including Beltsville, deals with soil and equipment relationships, pesticides and fertilizers application, crop conditioning, cotton ginning, environmental requirements (including light) for livestock, electromagnetic radiation for seed and plant product treatment, insect attraction and destruction, and nondestructive determination of fat and lean on live animals. Most of the work at other locations is directed toward solution of specific problems.

As a step toward implementation of the recommendations for a National Program of Research for Agriculture made jointly by the Association of State Universities and Land Grant Colleges and the USDA, a section has been added to each of the Areas in this report. It comprises a list of the related publications of the State Agricultural Experiment Stations in addition to those heretofore reported covering the results of USDA and cooperative research. Two examples of achievements resulting from State and State-USDA cooperative research are shown. In future years it is anticipated that this list will be expanded.

The program of the Agricultural Engineering Research Division is reported under 14 Research Areas shown in the Table of Contents.

The following examples are illustrative of research accomplishments for which the Agricultural Engineering Research Division (AERD) has had a major responsibility:

(1) Recent research points the way to use of models as quick and inexpensive tools for developing new tillage devices. Research has shown for the first time that the forces on moldboard type plows, operating in soils which are not idential and which have a wide range of soil strength values, can be predicted from models of the same configuration as full scale plows. The apparent cohesion and the angle of internal friction were found to be the dominant soil properties used in predicting the forces on these tools.

(2) Agricultural engineering research has made possible the effective ginning of the machine and rough hand-harvested seed cotton. The developments of this research program have been a primary factor in maintaining the competitive position of cotton.

(3) In cooperation with several State Experiment Stations, good progress has been made in mechanizing the harvesting and farm handling of several fruit crops destined for processing outlets, including cherries, blueberries, prunes, and dates. This is particularly true for tart cherries where labor requirements have been reduced by 75 percent and costs by 50 percent.

(4) Seed cleaning research has resulted in the improvement of many existing techniques for processing given seed mixtures, either by performing a more precise separation with conventional equipment or by developing and using new equipment to better exploit seed differences. Commercial adaptation of this new knowledge has saved the seed industry several million dollars annually.

(5) Environment for livestock buildings--Research in cooperation with State Experiment Stations has obtained much needed basic data on the heat and moisture given off by cattle, hogs, and poultry, and on the influence of building environment on production and feed consumption. The heat and moisture dissipation data are considered basic design data for ventilation systems of poultry, dairy, and swine buildings. They appear in design handbooks including the Guide and Data Book of the American Society of Heating, Refrigeration, Ventilating, and Air Conditioning Engineers, and are used by makers of ventilating equipment, prefabricated buildings and package buildings as well as by specialists advising farmers on their own construction. Building improvements resulting from the above research have contributed to the substantial rise in efficiency of livestock production that has occurred during the past decade.

(6) The first field scale test of light traps for insect control was initiated, in cooperation with the Entomology Research Division, in a 113-square-mile area in North Carolina in 1962 with 366 traps of special design. This has been enlarged to cover 315 square miles with more than 1,000 traps. Efficiencies of several trap designs are being studied. The results of the 4-year period, 1962-5, have been very promising and have indicated that hornworm moth populations in the tobacco area can be reduced considerably by use of electric insect traps when installed at a density of 3 per square mile over an area at least 12 miles in diameter. The island of St. Croix, Virgin Islands, with an area of about 84 square miles, was also covered with light traps at a density of 3 per square mile during 1965 to provide an area as nearly isolated from insect infiltration as possible. This is expected to provide a desirable location to determine possibilities of insect population suppression by means of electric insect traps alone or in combination with other methods.

(7) Research on maintenance of adequate voltage levels at farm electric consumers' meters led to development of the Altman method for determining the sizes of transformers needed to serve specific farms. The procedure, developed by an agricultural engineer of the Agricultural Engineering Research Division, L. B. Altman, in cooperation with the Iowa Agricultural Experiment Station and the Rural Electrification Administration, was applied on 698 farms served by a Kansas rural electric cooperative. The savings and improvement of service effected by use of the Altman formula far outweighed the additional cost of the necessary record keeping. Consideration of general use of this method has been recommended to all electric cooperatives by REA engineers.

The following two examples of research accomplishments were supplied by CSRS:

(1) A substantial saving in the cost of harvesting dates has resulted from cooperative research at the Citrus Experiment Station by the California Agricultural Experiment Station and the USDA Agricultural Research Service.

Approximately two-thirds of the 1965-66 crop of 36,000,000 pounds of dates was harvested mechanically. The contract price for hand harvest was 1.875 cents per pound; for mechanical harvest, 1.0 cents per pound. Thus, the actual reduction was over $200,000 for this season alone.

This project was initiated in the fall of 1961, at the request of the Date Administrative Committee of Indio, California. Preliminary studies indicated that, contrary to tradition, dates could be removed from an entire bunch by vibration in about 5 seconds, and that adequate maturity without loss could be obtained, concentrating the harvest of a garden into only two "pickings." Within 3 years, experimental equipment was developed and successful systems for commercial use followed quickly. The cost of the research has been saved several times over in a single season.

Mr. B. J. Peightal, Manager, Date Administrative Committee, and Mr. Telles Codekas, a prominent grower, expressed to Dr. C. F. Kelly, California station director, the opinion that this work is "the most remarkable in the date industry in a 50-year period."

(2) Successful mechanical harvesting of processing apples requires that fruit shaken from the tree be collected without excessive bruising. Research at the Agricultural Experiment Station of Cornell University has resulted in development of such equipment. The unit is self-propelled and sufficiently maneuverable for orchard operations. All wood and metal surfaces are cushioned by plastic foam to reduce damage to falling fruit. Maximum height of the machine permits use under low-pruned and heavily loaded trees. Two of the machines are used with one on each side of the row. When used with an inertia-type shaker and a maximum crew of 4 men, 150 to 200 bushels per hour can be harvested thus replacing 15 or more hand-pickers. Quality of the apples harvested is comparable to that of typical hand-picked fruit.

AREA NO. 1: - SOIL - MACHINE RELATIONSHIPS

Problem. The substitution of the internal combustion engine for animal power has been the major influence on the farmer's productivity during the first half of the twentieth century. There have been important developments in the tractor chassis and its accessories, such as tricycle chassis, power take-off, implement mounting, hydraulic controls, and pneumatic tires, but there is still a lack of fundamental knowledge and understanding of the method whereby tires and tracks transmit forces to the soil in developing traction. In view of the tremendous amount of power and energy which is used every year in farm field operations, all factors which may affect the efficiency of this use should be continually studied for potential improvements in efficiency.

There is need for basic information on how traction is developed by tires and tracks, and need for improved traction, and transport equipment. There is evidence that compaction of soils is becoming more common because of the increasing size of tractors and the more complete mechanization of field operations, particularly harvesting, which usually must be done at a given date regardless of the soil conditions; thus, associated with tire and track research is a need for study of methods of reducing soil compaction.

Tillage of the soil is the greatest consumer of power in the production of crops in the United States today. Some type of tillage operation is considered necessary prior to the growing of almost all crops. Despite this great need and cost, the tillage tools which are generally used have remained essentially unchanged since their invention, or most radical improvement, nearly 100 years ago, and very few innovations since have survived the tests of improved response of crops and/or reduced cost of operation. While some tillage is needed for nearly all crops, there is good evidence that much unneeded and in some cases detrimental tillage operations are performed. The soil is a very complex physical system, containing inorganic and organic solids, liquids and gases, and its reactions to forces, manipulation, temperature, and water is unlike any other simple material. In view of the wide-spread use of, and great power consumption by, tillage, there is a need for expanded basic research to give more precise information on the inter-relationship of tillage, soil physical conditions, and plant growth; on the effect of soil mechanics upon the tillage operation; on the effect of equipment mechanics on the tillage operation; on mathematical methods which can be used to predict the effect of various forces on the soil; and on tillage methods and systems of equipment which are compatible with conservation farming practices. Intensive research is needed to determine the optimum tillage requirements, based on costs and crop response, for various soil, climatic and crop conditions.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers and soil scientists engaged in both basic studies and the application of known principles to solve problems dealing with the relationships between soil-engaging equipment and soil reactions. The research findings are applicable to tillage implements, tractive and transport equipment (such as tires, wheels, and crawler tractor tracks), and soil moving equipment (such as land forming and road building equipment). Work is cooperative with the State Agricultural Experiment Stations at Auburn, Alabama; Ames, Iowa; and State College, Mississippi. USDA personnel working on this project are stationed at Auburn, Alabama; Ames, Iowa; Stoneville, Mississippi; and Shafter, California. Much of the work at the National Tillage Machinery Laboratory at Auburn is cooperative with manufacturers of implements and equipment for use in agriculture. The research is of a fundamental nature of value to the entire industry and directly and indirectly to farmers. It consists of theoretical analyses, basic laboratory studies, controlled soil bin tests and field observations.

The Federal scientific effort devoted to research in this area totals 10.8 scientific man-years. Of this number 2.0 is devoted to traction and transport devices and soil reaction; 1.0 to the effect of tillage practices on plant growth; 1.6 to the measurement of soil physical properties; 2.5 to equipment mechanics; 2.2. to the effect of soil mechanics; 0.5 to methods of mathematical analysis; and 1.0 to systems of equipment for conservation farming.

PROGRAM OF STATE EXPERIMENT STATIONS

Many of the State agricultural experiment stations are engaged in both fundamental and applied research dealing with the development of new principles and the application of currently available knowledge to the problems concerned in soil-machine relationships in order to increase efficiency in crop production. These studies are concerned in the broadest sense with the development of theories, special devices, and laboratory and field tests to determine ways in which tractive and transport equipment, tillage tools and systems for their use might be improved.

Investigations are in progress on ways to develop and apply more efficient methods of soil manipulation that will produce improved soil physical conditions for seed emergence and optimum plant production; development and evaluation of systems of tillage which offer possibilities in reducing time, labor, or equipment to produce a crop; determination of fundamental and predictable relationships between external energy applications and soil breakdown and consolidation; exploration of techniques necessary for improvement of deteriorated soil structure and soil tilth; probing into possible ways that traction and flotation of farm machines might be improved to overcome the problems caused by compaction; and measurements of power

requirements, stresses and wear on tools and equipment as an aid to improved farming efficiency.

Many of these research investigations are cooperative with the Department. A total of 15 scientific man-years per year of research effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Traction and Transport Devices and Soil Reaction.

1. Studies were continued to determine the effects of tire diameter on traction tire performance. Additional tests using three diameters of tires on concrete and three soils were made to amplify earlier data. All data are being carefully considered and analyzed by members of the Traction and Transport Efficiency Committee of ASAE. Results indicate that though there is a complicated interrelationship between rim diameters, inflation pressures, tire deflection, and tire loading, other factors being equal, increasing tire diameter increases the coefficient of traction. Results will be published when members of this committee and the Laboratory staff are satisfied that the data are relatively complete and correct.

The cooperative study with Bell Telephone Laboratories to measure the traction capabilities of tracks on submerged soils was completed and two papers were published covering this work.

Two series of tests were made comparing the performance of two Dunlop tires made in France, a radial ply tire made in Italy and conventional American made tires. The cords in the fabric of one Dunlop tire make an angle of approximately 27^{o} with the center line of the tire. This compares to angles of approximately 45^{o} for the conventional American tires and 90^{o} for the radial ply. The manufacturer recommended operating this low cord angle tire at approximately 25 percent lower inflation pressure than that recommended by the Tire and Rim Association for tires of the same size and carrying the same load. The radial ply tire out performed all other tires under all test conditions. Lowering the lower cord angle tire inflation improved its performance. However, it did not surpass the performance for tires having conventional cord angles and did not nearly equal the performance of the radial ply tire.

B. Effect of Tillage Practices on Plant Growth.

1. Studies were conducted in cooperation with the Alabama Station to find the effect of crop preceding and position of crop residue on peanut production. A seven-year experiment with eight replications showed that there was very little difference in peanut yields whether the peanuts followed rye, corn, cotton, or soybeans. There was no difference in the yield of peanuts from plots that had the preceding crop residue removed, plowed under deep, or mixed with the plowed soil. This experiment was completed this year.

Studies were made in cooperation with the Alabama station to determine and evaluate basic factors affecting the design and use of deep tillage implements. The yields of cotton from all deep tillage treatments at the Ingram farm were slightly higher than the shallow tillage treatment. However, soil bulk density measurements indicated that most of the soil loosening effect of the fall deep tillage was eliminated in the spring planting and cultivation operations. For this reason this year all of the deep tillage plots will be ripped approximately 16 inches deep and planted in the same pass in the spring. On the Agricultural Engineering Research Unit, Auburn University, deep plowing (10 in. to 12 in.) significantly increased the yield of cotton over a five to six inch depth of tillage. Subsoiling and planting over the subsoiled slot in a separate operation increased cotton yields in three out of six locations over the state of Alabama. At one location the increase in cotton yield due to subsoiling vs. six inch depth of tillage was 47 percent.

An exploratory study was initiated in cooperation with the Tuskegee National Forest to eliminate kudzu by cutting it with a rotary tiller each time the leaves were almost full grown. The kudzu on a 2.5 acre plot was rotary tilled on May 11, 1965, June 3, 1965, July 17, 1965 and September 14, 1965 requiring 4, 3, 2, and 2 hours respectively. The surviving crowns of kudzu will be counted in 1966 and the rotary tillage will be continued if necessary.

2. A minimized tillage system was compared to a normal system at Shafter, California, for the fourth year. Results show improvements in soil conditions and plant growth for the minimized system. For the first time, yields were less in the minimized tillage system due to verticillium wilt. Two possible explanations exist. There is more crop residue in the soil surface in the minimized tillage system which may harbor wilt organisms. Also, it has been shown that verticillium wilt causes greater damage to more rapidly growing plants with greater fruiting loads. This work will be expanded in cooperation with Plant Pathology.

Precision tillage was shown to effectively reduce effects of increased soil compaction. Cotton yields were directly correlated with average soil strength under the row. There was also a large difference in soil density between traffic furrows and non-traffic furrows. Water infiltration was directly related to these differences. No difference in soil strength profile could be detected between plots precision tilled with normal or vibrating sub-soil shanks. The precision tillage test at Lubbock, Texas, was completed and a publication was issued. No significant improvements were obtained by sub-soiling under the drill row on the Amarillo loam soil at Lubbock.

3. Instrumentation for power requirements was completed for use on tractor-mounted tools. Draft measurements were correlated directly with penetrometer measurements and were found to be one method of measuring soil responses from previous tillage treatments. Draft measurements showed a

reduction for vibrating sub-soil shanks compared to normal shanks but no reduction in tractive effort. Energy required for rotary cultivators was found to increase with the relative velocity of the rotor blade and with the soil-to-rotor geometry.

4. In the soil mixing study at Stoneville, the deep treated silty clay shows some yield response to mixing sandy loam sub-soil with the clayey surface although not as great as in the first year. Mechanical analyses of soil samples taken from mixed and untreated profiles showed that in most instances the clay surface had been changed to a clay loam by the mixing process.

C. Measurement of Soil Physical Properties.

1. A manuscript of a U.S. Department of Agriculture Handbook, "Soil Dynamics in Tillage and Traction," was completed and sent to the Government Printing Office for printing. During this year the final revisions and editings were completed on the 1,250-page manuscript. Details concerning distribution and numbers to be printed were finalized. At this time it would appear that there will be about 3,700 copies printed, of which 175 will be hardback copies.

A wedge-shaped tool was drawn through the soil causing a deformation of the soil that was governed by the shape of the tool, the soil-tool friction, the manner of movement of the tool, and the type, condition, and degree of confinement of the soil. Last year's report showed the general nature of soil deformation that could be traced by marking pins. Work was continued by making detailed deformation measurements in a large confined soil mass. The theoretical soil deformation predicted from a model soil-tool system did not provide an accurate estimate of actual deformation.

Yielding by compaction and shear in unsaturated soil was studied by applying forces to volume elements of soil in a triaxial apparatus. Procedures were similar to those reported in the 1963 annual report but were modified so that continuous analog techniques could be used. Vertical force and water pressure applied to the soil sample were varied slowly and, along with volume change and change in axial length, were continuously measured and recorded on magnetic tape. With the final volume and length of the soil sample known, the state of stress and state of compaction were continuously calculated with an analog computer from the data recorded on magnetic tape. Each test resulted in a loading path which defined parts of two surfaces in a three-dimensional stress-density space. This stress-density space shows the interaction between density and shear.

Requirements for a root environment were observed in the field, using cotton in cooperative subsoiling tests with SWC and Auburn University. These field studies allowed observation of root development in many variations of soil pH, soil density, soil nutrient status and porosity

geometry. The rooting characteristics of the local cotton varieties and the effects on the soil and on root development produced by the current cultural system employed to grow cotton in the Southeastern United States were also observed. Laboratory studies on soil strength, air permeability, and pore geometry have been employed to characterize various soils under many bulk density and moisture situations. Root development in identical soil bulk density and moisture situations is being correlated with these laboratory studies using cotton grown in the controlled environment chamber.

D. Equipment Mechanics.

1. In similitude studies draft and vertical forces and their moments in the respective planes were measured on two plane vertical chisels (1 inch and 2 inches wide) in a sandy loam and a clay soil. The forces were obtained with the chisels operating to a maximum depth of six inches at a constant speed in the circular model bin. Soil measurements obtained were bulk density and resistance to penetration of a cone penetrometer. Moisture content was also obtained. The draft pi-term was found to vary linearly with the second power of the depth/width pi-term.

Abrasive wear and friction-adhesion studies were made comparing 23 compositions of steel using the wrought iron wheel and sand wear test method. These samples were furnished by U.S. Steel Corporation. Statistically there were some differences in wear; however, the differences in wear resistance were not large. The differences in friction-adhesion among all steel samples were also small. Brinley-Hardy Company also furnished plows with a new Tenelon stainless steel and a production steel. These were run in the field. The Tenelon wore slightly faster than production steel. Monsanto Chemical Company also furnished three plastic samples. These plastics had slightly better wear resistance than Teflon but much higher friction-adhesion on soil.

Tests were conducted cooperatively with the Oliver Tractor Company on moldboard plows. The primary objective was to determine the effects of certain plow geometries on forces exerted by the soil at high speeds. At 6 mph an 8^{o} decrease in the angle between share and furrow wall with a corresponding decrease in the vertical approach angle of the share and moldboard decreased the draft by 24 percent compared to their standard bottom. A 5^{o} increase in the same angle with a decrease in radius of curvature of the moldboard which tended to restrict soil flow increased the draft by 13 percent. The total draft of an experimental Oliver high speed 16 inch plow was approximately equal to that of a 14 inch general purpose bottom. In general, the rate of increase in draft from 4 to 6 mph was lower for high speed bottoms of three companies than that of a general purpose bottom. These high speed bottoms turned the soils satisfactorily at speeds of 3 to 6 mph. Formerly some high speed bottoms have not turned the soil satisfactorily at low speed.

An attempt was made to evaluate the draft characteristics of the Ford General-Purpose moldboard plow bottom and the Case EX-14 bottom in compariso with bottoms studied in 1961 (Oliver 619 with 419 bottom, I.H.C. H5 CX-14, John Deere HS-434-14, and Allis-Chalmers 375-14). The second portion of the test was to evaluate the draft characteristics of a share mounted fin (Rooster Comb) on the Ford bottom. Differences in draft between any of the bottoms tested were not significant. There were pronounced changes in furrow characteristics, especially at the higher speed. Changes in furrow appearance with speed may be a more important consideration than draft for high speed bottoms. The fin had less draft in both sandy loam and the clay loam than a rolling coulter. It added practically no draft to the bottom with no accessories. The fin significantly lowered side force and would possibly reduce landside wear appreciably.

In cooperation with Massey-Ferguson a study was continued to obtain the validity of predicting the forces on a multiple bottom plow from tests with a single bottom. From measurements in three soil types it was concluded that reasonable predictions can be made.

Studies were made with Lilliston Implement Company on the soil forces acting on a double scale rolling cultivator slicer tine XT-1. This study resulted in their making eight new experimental shapes. These shapes were then studied. The studies should help them to improve their rolling cultivators for certain applications.

Studies of full scale equipment will be continued as requested by industry as long as new information is being obtained that can be made available to the entire industry.

E. Systems of Equipment for Conservation Farming

1. Studies were initiated in cooperation with the Iowa station to evaluate the use of herbicides and tillage practices for 30-inch-row corn production. Overall spray applications of atrazine, simazine, and 2,4-D were made in early spring on unplowed and spring-plowed cornstalk ground. Secondary tillage operations included disking, strip rotary till planting, and no tillage. Adequate rates of fertilizer were applied so that fertility level could be eliminated as a variable. The control or check treatment to which all others were compared was conventional moldboard plowing, disking, and spike tooth harrowing. Mechanical cultivations were performed as weed infestations demanded. Because of adverse weather conditions during the month of May, it was impossible to perform the secondary tillage operations or to plant until early June. This resulted in variable stands and low yields. Because of this, it was impossible to draw specific conclusions from this experiment. There were, however, some trends in the data that are of interest. Early applications of simazine and atrazine gave substantially better weed control with only one mechanical cultivation than the unsprayed plots or the plots that received 2,4-D as a spray. In all instances, the lowest stands, poorest weed control, and lowest yields

occurred where no secondary tillage was performed. Previous work had indicated that adequate weed control was obtained without secondary tillage. The results this year indicate a need for secondary tillage not only from the standpoint of establishing adequate stand but also for obtaining better weed control. The trends indicate that corn can be produced in 30-inch rows with little or no seedbed preparation if adequate stands and weed control are obtained.

Studies were initiated in Iowa to compare ridge and conventional planting of corn and soybeans using 30-inch row spacings. Because of the narrower row spacing, the ridges were somewhat reduced in height and width. Faster emergence and equivalent yields were obtained when weeds were controlled chemically. Mechanical cultivations were somewhat more difficult for both ridge and flat planted corn and soybeans when the 30-inch row spacings were used. Chemical weed control appears to be more consistent with the ridge planting system.

Studies were initiated in Iowa to evaluate tillage systems under a high level of fertility and good weed control obtained through the use of preemergence applications of atrazine sprays in corn. The following systems were evaluated: (1) strip rotary tillage, (2) listing, (3) conventional disking and harrowing, (4) ridging, (5) Missouri till planter, (6) Dempster till planter, (7) dragging hoe, (8) disking, (9) strip tillage with a cultivator sweep, (10) no tillage. These systems were evaluated on fall plowed land. Adverse weather conditions made it necessary to delay the secondary tillage operations until early June. This resulted in a low level of corn production and makes the results somewhat tentative. Trends in the data indicate that the omission of tillage resulted in fewer stalks per acre, a heavier weed infestation, and lower yields. Among the tillage systems, the yields, stands, and weed weight differences were quite small, indicating that all performed equally well. These results indicate that the tillage systems under test will probably be successful on 30-inch corn in the same manner that they were successful on 40-inch corn.

In cooperation with the Iowa station, the model tillage laboratory was used to study the influence of a simple oscillating tillage tool on the formation of soil clods. Clod size determinations were made before and after the tillage operations. Preliminary results indicate that the forces, velocities, and energy inputs along with the physical properties of soil can be correlated with the mean weight diameter of the resulting clods. It appears that the total energy inputs are somewhat reduced by oscillations.

F. Foreign Research Under Public Law 480 Funds.

1. Work has continued on a three-year project by the University of Bologna, Bologna, Italy, on development of methods and equipment for breaking up cohesive clay soils into small clod sizes up to a deep depth. Their work for us began in October 1963, and includes work in the laboratory and in the field. They are attempting to clarify the relationships existing

between the force of traction and energy required by the various agricultural tools designed for principal tillage, and the effects which the tillage itself produces upon the clay soils such as those in the Po Valley.

Several moldboard plows are being compared with other tillage devices. The largest moldboard plow (Nardi) is capable of reaching a depth of about 36 inches, and is of the type commonly used in Italy for very deep tillage for orchards and vineyards. However, this plow could not be tested this year because of unusually heavy rains, and is scheduled to be tested next year. Two rotary plows (Civello) with vertical axes, one combination moldboard plow with a rotary coulter, (Nardi type misto), and a special experimental subsoiler for depths up to 24 inches, are included in the tests. Test measurements include such items as furrow characteristics, force of traction, fuel consumption, and percentages of clods classified by weight and volume. The results are not yet complete enough to give comparisons between the different tillage tools.

2. In May 1965, a three-year research project was started by Volcani Institute of Agricultural Research at Rehovot, Israel. This research concerns the influences of tillage operations on soil physical conditions related to crop growth. In a dry farming experiment three primary tillage treatments were performed in August 1965: moldboard plowing 10 inches deep, moldboard plowing 16 inches deep, and chisel subsoiling 16 inches deep. This field was to be planted in grain sorghum in April 1966. Auxiliary experiments are being conducted in an adjacent field to evaluate minimum tillage and planting methods for sorghum.

In an irrigated farming experiment conducted by the Volcani Institute the problem of soil structure management is of the most concern. Hence this experiment is aimed more specifically at methods of preventing compaction and maintaining desirable structure in the seed and rooting beds. The same three primary tillage treatments mentioned above were performed in November 1965, as well as a minimal tillage treatment (disk harrowing, no plowing or subsoiling). In addition, two ridging treatments were included: permanent ridge-beds (precision tillage by subsoiling performed in autumn) compared to shifting ridge-beds (one year's furrow becomes the next year's ridge). This field was to be planted in cotton in April, 1966.

3. In July 1965, research was started on a three year project by the Volcani Institute for Agricultural Research, Beit Dagan, Israel, to find the effect of knife angle and velocity of cutting of roots and rhizomes in the soil. Two widespread and troublesome weeds with different types of root systems were selected for the tests: Bermuda grass (Cynodon dactylon) and field bindweed (Convolvulus arvensis) were selected. Bermuda grass has a rhizomatous shallow root system, while field bindweed has deep penetrating true roots.

Preliminary tests were conducted on the basic mechanical properties of Bermuda grass rhizomes. Maximum force (tearing force) varied from 7.1 lb. to 29.8 lb. for rhizomes of 2 to 3.5 mm. in diameter and 10 inches in length. The rhizomes were torn at the joint. Knives with different degree of sharpness were used to press the rhizomes into the soil, but no difference was observed between dull and sharp knives in regard to the number of rhizomes torn by tension rather than being cut, under the conditions of the test. The soil used consisted of sand at 1.6 g/cm^3 bulk density and 3.2 percent moisture content.

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AREA NO. 2: PLANTING AND FERTILIZING OPERATIONS AND EQUIPMENT

Problem. The history of the development of planting equipment now in use is characterized primarily by invention of machines which will plant seed in accordance with accepted practices. Introduction of chemical fertilizers was followed by specialized equipment for spreading this material. Early work on placing fertilizer close to the seed (starter fertilizer) was followed by the discovery that a certain position with respect to the seed resulted in the best response to starter fertilizer for particular crops.

However, there has been very little work on, and there is considerable present need for, precise seedbed requirements for various crops in different areas of the country. This seedbed requirement would include depth of cover, size of soil particles or clod surrounding the seed, degree of soil compaction necessary, and soil surface profile over the seed for best emergence. The row spacing used on many crops is still that which was necessary to permit horse cultivation. The exact best planting geometry for many crops is still unknown. The exact best placement for starter fertilizer is also unknown for a number of crops in different areas of the country. There is also a need for development and testing of fertilizer application equipment for unusual crop situations, such as hillside orchards, sugarcane, tree transplants, etc. While efforts in precision planting of crops in the pas have not often resulted in discernible yield improvements, there is a renewed interest in precision planting of vegetables to improve uniformity of maturation to facilitate mechanical harvesting. As other needs for hand labor diminish and it becomes less available on farms, there will be an increasing need for completely automatic transplanting equipment which does not yet exist. There is an acute need for new and improved equipment and methods for effective planting of native range grasses in the arid areas of the Southwest which will result in a greater certainty of stand. Equipment is needed which can be used to re-seed relatively rough areas which are overgrown with undesirable species or have recently been cleared. There is also need for improved planting equipment and methods for forage crops in humid areas. Approximately a third of such plantings now result in poor stands and another third result in no stands at all.

The greatest need in cotton production is cost reduction. Seedbed preparation remains one of the costliest operations in production in many areas; and planting is plagued by the uncertainty of getting a stand and the urgency of timeliness and precision. Research has begun to develop optimum tillage systems in some areas but they need further development and extension into other soils and climates. Although some progress is being made, more basic knowledge of the micro-environmental requirements of the cotton seed is needed; and this needs to be translated into planting

equipment to give better precision in the control of seedbed physical conditions. Better control of the seedbed shape, size, spacing and seed position will also have a direct bearing on the economy of using new and more potent pesticides.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of applied engineering research on planting methods and means of applying fertilizer on various crops. Cooperative studies are in progress in ten states (Florida, Georgia, Louisiana, Maryland, Nevada, New Mexico, Oklahoma, Tennessee, Texas, and Washington). The professional staff members with their respective laboratory and engineering facilities are headquartered at three locations: in the East at ARC, Beltsville, Maryland; in the Southeast at Athens, Georgia; and in the Southwest at Bushland, Texas. Forty-three field experiments were conducted cooperatively in 1965 with either State experiment stations, other ARS Divisions, or some commercial research units.

In the spring of 1958, cooperative endeavor was requested of ARS to determine effective means of removal of hazardous contamination to agricultural lands that may result from nuclear explosions, by use of farm and industrial equipment. This work is cooperative with SWC and is conducted under contract and funds of the Atomic Energy Commission.

The Federal scientific effort devoted to research in this area totals 7.0 scientific man-years. Of this number 0.8 is devoted to fertilizer placement and distribution equipment; 0.1 to seed planting equipment; 0.1 to transplanting and fertilizing equipment; 1.4 to equipment for establishment of forages; 2.0 to cotton seedbed preparation, planting, and fertilizing equipment; 0.6 to vegetable planting equipment; and 2.0 to decontamination of agricultural land.

PROGRAM OF STATE EXPERIMENT STATIONS

Problems concerned with planting of the many sizes and shapes of seed of agricultural crops together with the introduction of fertilizers for use by these crops are under attack by many of the State Agricultural Experiment Stations. A considerable amount of this work is cooperative with the Department. These studies are concerned with the development of new principles that can be used to meter and place seed which could lead to planter improvement. Similar investigations are in progress to develop satisfactory metering and placement devices for application of liquid as well as solid fertilizers. In both instances the principal objective is to provide the best possible means of seed and fertilizer placement which will assure healthy plant emergence with vigorous growth to maturity.

Involved in these studies are design and testing of the several elements of machines together with investigations of the mechanics of seedling emergence. Basic research is also underway in an effort to determine the

environmental conditions that are necessary for maximum emergence and how these conditions may be controlled or altered with mechanical equipment. Companion to these overall studies are limited testing, improvement and development of equipment for aerial applications of seed and fertilizer.

A total of 9 scientific man-years per year of research effort is devoted to this work.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Fertilizer Placement and Distribution Equipment.

1. Eleven field experiments on the establishment of field crops and vegetables were put in cooperatively with various State and Federal research units. These experiments were put in at eight locations, which are within the bounds of six states (Florida, Georgia, Maryland, Nevada, Texas and Washington). Some typical results or trends shown of the field crops are: the yield of grain on winter oats at Watkinsville, Georgia, with 80 lbs. per acre of seed drilled in four inch rows with fertilizer placed one inch to the side and one inch below the seed row was increased about 30 percent over a similar seeding in eight inch rows. Another seeding drilled in four inch rows, but with the fertilizer placed in contact with the seed, produced grain yields about 19 percent greater than a similar seeding in eight inch rows. The recommended fertilizer used was 600 lbs. of 5-10-15 per acre. (Typical results for vegetables are given under Vegetable Planting and Fertilizing Equipment.)

B. Equipment for Establishment of Forages.

1. Thirty-two field experiments on the establishment and production of pastures and haylands were put in or continued from the previous year in cooperation with various State and Federal research units. These experiments were put in at eleven locations, which are within the bounds of eight states (Georgia, Louisiana, Maryland, New Mexico, Oklahoma, Tennessee, Texas and Washington). Some typical results or trends shown of the forage studies are: interseeding of high quality grass into stands of low quality plants with minimum disturbance has been conducted at Pantex, Texas in 1963-65. The late May date of seeding appears to be the best date of seeding on the Texas High Plains. March and April plantings generally have fewer grass seedlings and more weeds than later plantings. This work will be summarized for a publication in 1966. The influence of soil compaction on grass establishment has been studied at Big Spring, Texas, from 1963-65. The comparison of bulk density in 1965 with measurements made in 1963 indicate that the low soil densities are becoming more dense and the high densities becoming less dense. The field work on this experiment is scheduled to continue in 1966; however, since the Big Spring Field Station is scheduled to be discontinued in July 1966, the experiment probably will then be terminated. Plant materials, fertilizers, and cultural practices in relation to stabilization of sand dunes have been studied from 1963-65 near

Guymon, Oklahoma. The most promising economical approach to stabilizing the dunes is to encourage growth of existing species through fertilization. Analysis and summary of this work are scheduled for 1966. From investigations cooperative with the Georgia station, it was found that the use of herbicides in the sprigging of Coastal bermudagrass is quite important -- is much more important when ample moisture is available the first few weeks of establishment than in seasons with little moisture (1964 experiment had no moisture the first six weeks -- 1965 experiment had good moisture up to first forage harvest in October). Water with sprigs as set (irrespective of herbicides) gave best initial stands, and survival stands (through first winter) of all methods when season moisture was poor. With ample moisture, establishment using water with sprigs was about equal to water applied as irrigation. The common method of applying fertilizer only after the sprigs show life gave poorest initial and survival stands during both seasons. With two more or less exploratory seasons completed, and trends showing considerable differences between good and poor moisture seasons, a new means will be used for the next season to get a series of tests under limited moisture conditions. An area 120 ft. x 24 ft. is being provided with removable covers, to be used for field plot experiments with controlled moisture. It is expected this new control will give results under adverse growing conditions much quicker and will provide more comparable data and, therefore, more reliable results.

In Western Washington phosphorus fertilizer broadcast on forage plots remained concentrated in the surface inch of soil, while potassium moved appreciably downward into the root zone. This localization of phosphorus has also been noted in other humid areas. Phosphorus must be applied near the seed or feeder roots for maximum efficiency.

2. Work has continued under a contract with the New Mexico station to develop machinery to seed rangeland. Most of the work was accomplished at the Jornada Experimental Range, New Mexico, on sites where creosotebush and tarbush are the major types of undesirable vegetation. The primary objective of the research is to modify existing equipment, or to design equipment that will accomplish the following four operations in one pass over the land: eradicate undesirable shrubs, provide a firm seedbed, place seed accurately and windrow uprooted brush over the planted strip. Three basic units have been used thus far in the investigation to accomplish the above objectives: (a) a rootplow to eradicate brush, (b) a seeder to firm the seedbed behind the rootplow and accurately place grass seeds, and (c) windrowing equipment to place uprooted brush over the planted strip to protect emerging plants.

Two basic units of the equipment remain unchanged from the previous year: (a) The Fleco Rootplow for brush eradication, and (b) the "New Mexico" Nisbet Range Seeder for firming the seedbed and planting the seeds. A D-7 caterpillar tractor is the source of power for the operation. During the period of this report, two models of a side-delivery windrower have

been constructed, and a baled hay loader has been modified to investigate the feasibility of carrying the uprooted brush over the top of the seeder and depositing the residue immediately behind.

The following problems were encountered with the first model of side delivery rake tested: the tines did not have sufficient strength and several were deformed or broken during field trials, and the rotational acceleration and deceleration of the carts as they passed around each of the four sprockets at the corners caused failure due to fatigue in the connectors between chain and carts, and in the bolts which attached the carts to the connectors. Changes considered necessary have been made in the first model of the side delivery rake, and a second model is now ready for testing.

A traction-powered, baled hay loader was modified, under the New Mexico contract, to pick up the uprooted brush and elevate it to a height sufficient to drop it behind the Nisbet seeder. The modification consisted of attaching two 7-inch x 3/8-inch round steel rods to each of the lugs on the two hook chains of the loading mechanism, and removing the narrow, vertical side boards along the elevator platform and replacing them with wide sheet metal "wings" at a 30° angle from the horizontal. Preliminary tests have indicated the feasibility of moving the brush with the baled hay loader. The 7-inch spikes on the chain appear to be of sufficient length to pick up the brush and carry it up the platform inclined at approximately 40° with the horizontal. Other tests will be made using steeper slopes until the maximum slope is determined at which the brush can be carried up the incline.

C. Cotton Seedbed Preparation, Planting and Fertilizing Equipment.

1. In crop residue disposal studies at Stoneville, Mississippi, additional modifications were made on the commercial shredder-tiller machine obtained for this study in 1963. More uniform distribution of shredded residue was obtained, troublesome "piling" was reduced, and field efficiency was improved. A herbicide applicator attachment permitted incorporation of a 20-inch band of pre-planting herbicide in the same operation.

2. In planting equipment tests at Stoneville, planting equipment in some instances has produced undesirable soil conditions for miximum cotton plant emergence. Higher soil bulk densities and higher soil strengths resulting from the use of special heavy equipment at planting have delayed emergence, reduced stands, and reduced yields. This is a widespread farm problem of obtaining too much compaction in trying to achieve more precision in size and shape of seedbeds. Investigations of sled tool carriers and equipment for cotton production indicated that higher speeds, more precision, and greater field efficiencies are possible where planting and cultural practices are linked to a common tool carrier. Bed shapes and bed spacings, specially fitted to accept sled tool carrier equipment and to limit traffic zones, were equally as productive as the conventional 40-inch system. Compacting the covering soil at Lubbock, Texas, during the planting operation with as

little as 0.60 psi reduced cotton emergence on Amarillo loam and Amarillo fine sandy loam soil. The seed press wheel was used to press the seed into the seed furrow before covering. Loose soil covering with no pressing gave the maximum seedling emergence. Precision depth planting on shaped beds again gave the best emergence under adverse weather conditions and required less seed.

In a study of the relationship of plant population and hill spacing to the development of efficient systems of cotton production at Stoneville, as in 1964, varying plant populations and hill spacings of cotton produced exceptionally wide variations in plant characteristics and some differences in yield. In 1965, 12-inch hill spacings having one and two plants per hill produced two of the three top yields; but a 24-inch hill spacing with three plants per hill produced the highest yield of 2,817 pounds of seed cotton per acre, compared to an average of 2,529 pounds. At Lubbock, cotton was planted flat in rows spaced 5, 10, 20, 30 and 40 inches apart and on beds with two rows per bed, spaced 4, 8, 12, and 16 inches apart on 40-inch beds. Plant populations ranging from less than 20,000 to more than 500,000 plants per acre were used in these tests. A relationship between seeding rate and percent seedling emergence was not readily apparent in these studies. The highest yield in the test was in the 5- and 10-inch rows at the plant population in the test that most closely approximated a 5 x 5 and a 10 x 10 inch plant spacing. In the double row test, the two rows 12 inches apart produced the highest yield which was approximately 10 percent more than the regular 40-inch single-row spacing. A dwarf-type maturing cotton strain and conventional early maturing stormproof strains planted in 10-inch rows out yielded the same cotton planted in 40-inch rows. In 1965, this yield difference in irrigated cotton was as much as 350 pounds of lint per acre.

3. Micro-nutrient and sulphur trials have been conducted on a cut and fill area, Lubbock, Texas, for the past three years. Average yields of lint cotton do not indicate a response to zinc or sulphur, or to iron and zinc in combination.

D. Vegetable Planting and Fertilizing Equipment.

1. The series of field experiments in cooperation with the Florida station on four vegetables was reduced to one in 1965 due to the plan to terminate the project as of July 1 (for the first four months of 1965). The other three studies are now being resumed for 1966. South Carolina Experiment Station has requested our cooperation on a series of seeding and fertility studies with corn and cotton at two or three locations in their state. It is planned to provide special field equipment and assist in putting in the field experiments this coming season.

Fertilizer placement studies and the use of an asphalt mulch spray on potatoes at Logandale, Nevada, gave no significant difference for the various treatments. Rates of fertilization were highly significant with

the 200 pounds of N out yielding the 100 pounds of N. The phosphate also contributed to these higher yields. Due to restrictions on travel, the project did not actively assist in the 1966 experiment, but research equipment was made available for use by the Nevada Agricultural Experiment Station.

Experiments with cannery peas in cooperation with the Western Washington station indicate phosphorus fertilizer should be placed two inches below the seed while mixed fertilizer is better placed one-half inch to one inch to the side and one and a half inch to two inches below seed level. Treble superphosphate salt effects are noted at rates of 90 lbs. P_2O_5 per acre in contact with seed; 30 lbs. P_2O_5 in contact with seed gave maximum starter effect. On sweet corn, fertilizer banded 2 inches x 2 inches or 3 inches x 3 inches (side x below) from the seed was satisfactory only up to 80 lbs. N + 80 lbs. P_2O_5 per acre. For higher fertilizer rates (120 lbs. N + 120 lbs. P_2O_5 per acre or 160 lbs. N + 160 lbs P_2O_5 per acre) the best placement was 2 inches x 4 inches or 4 inches x 2 inches.

E. Decontamination of Agricultural Land.

1. These investigations were conducted for the Atomic Energy Commission, in cooperation with SWC, to determine means of reclaiming farmland which has surface contamination with radioactivity. Previous research on this project has determined the effectiveness of common farm machinery for removing the top radioactive soil; however, the disposal of this soil still was a problem. A large moldboard plow capable of plowing three feet deep was modified to obtain effective burial and was used last year in some preliminary trials where the top layer of soil was scraped from the surface and dropped into the bottom of the furrow.

Before attempting a plant uptake program involving large expenditures for a strontium 85 isotope, attempts were made in 1965 to determine if crops could be made to grow on the sterile subsoil brought to the surface by deep plowing. About an acre of land at Beltsville, Maryland, was plowed to a depth of three feet, and rye, Swiss chard, cabbage, sweet clover, corn, New Zealand spinach and soybeans were planted on it. It was found with proper liming and fertilizing the subsoil could be made to produce nearly as well as the topsoil; however, there was a great variation in subsoil in the plots. The tests showed it would be safe to proceed with uptake studies using homogenous soil. More extensive deep plowing tests will be made in West Texas in 1966.

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AREA NO. 3: CROP PEST CONTROL TECHNIQUES AND EQUIPMENT *

Problem. Many pests attack economic crops in the United States, resulting in billions of dollars of loss to the farmer each year. Plant diseases, weeds, insects, and nematodes are examples. Every method to control or eradicate any of these pests requires some type of equipment. Effectiveness of the equipment necessary may be essential to the success of the methods which is attempted or recommended.

Thus, equipment to control a wide variety of pests on a wide variety of crops is required. This requirement is partially met by the sprayers, cultivators, dusters, and soil injection equipment now available. However, mechanical cultivation does not always produce satisfactory weed control, and it is time consuming and costly. It is believed that with sprayers and dusters now used,often no more than 10 to 20 percent of the chemical goes onto the plant. Methods of applying nematocides in the soil do not always result in uniform nematode control, and untreated soil below the treated zone, in untreated pockets, and at the soil surface, provides sources for quick reinfestation.

There is need for improved methods of much greater efficiency for applying pesticides to plants and the soil. This implies a need for considerable fundamental study of small particle behavior, of radically new methods of applying chemicals, and of the movement of liquid and gaseous chemicals in the soil. The sales of present equipment are not great enough, nor are the manufacturers large enough, to permit industry to make a very great investment for research in this field.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers, physicists, and mathematicians engaged in both basic studies and the application of known principles to the solution of farmers' problems. Cooperation is with the State Agricultural Experiment Stations of the states mentioned, unless otherwise noted. At Wooster, Ohio, basic research is conducted on fundamental studies of aerosols and on various spray formation devices. Soil fumigation research also is conducted at Wooster, Ohio. Chemical insect and disease control research is conducted at the Grain Insects Research Laboratory at Tifton, Georgia, chiefly on corn insects; at Ames, Iowa, particularly for corn borer control; and at Wooster, Ohio, on improved equipment for corn borer control. Disease control research is also conducted at Wooster, Ohio. Weed control research, chemical and cultural, is conducted at Ames, Iowa and Columbia, Missouri.

* Except electric, which is in Area 11.

Aircraft application equipment is studied at Beltsville, Maryland, in cooperation with the Forest Service; and at Forest Grove, Oregon, in cooperation with the Oregon and Washington stations and ENT, on low growing crops. Pest control equipment research for certain crops is conducted: for cotton at Auburn, Alabama; Stoneville, Mississippi; Shafter, California; Lubbock, Texas; and (particularly for boll weevil control) at State College, Mississippi; for vegetable crops at Forest Grove, Oregon; and for brush control at Mayaguez, Puerto Rico and College Station Texas.

The Federal scientific effort devoted to research in this area totals 17.4 scientific man-years per year. Of this number 1.1 is devoted to basic studies in aerosols and spray formations; 1.0 to soil fumigation; 1.7 to insect control in grain; 1.7 to weed control in corn and soybeans; 5.6 to pest control equipment in cotton; 0.5 to insect and disease control by ground equipment in vegetables and other low-growing crops; 1.0 to insect and disease control by ground equipment to fruit; 1.3 to aircraft equipment for application of pesticides to vegetables and other low-growing crops; 1.5 to aerial spray equipment for forest insect control; and 2.0 to brush control equipment and methods.

PROGRAM OF STATE EXPERIMENT STATIONS

Both basic and applied research investigations which have been designed to discover and develop methods, techniques, and equipment for control of the many pests that attack our economic crops are in progress at the several Agricultural Experiment Stations. Much of this work is cooperative with the Department.

These studies are involved in the complicated objectives of furthering the efficiency and the means for better control of insects, plant diseases, nematodes and weed problems through application of engineering knowledge on the use of aerial and ground chemical applicators for liquids and dusts, flame cultivators and mechanical devices for soil manipulation and soil fumigation.

A total of 7 scientific man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Studies in Aerosols and Spray Formation.

1. Theoretical and experimental studies on the basic transport and dispersion processes for fine particles suspended in turbulent fluids were continued at the Pioneering Research Laboratory on Fine Particle Physics at Wooster, Ohio, in cooperation with the Ohio Center. Work on continuous scanning of fluorescent-particle-traced aerosol deposits on solid surfaces was continued with adaptation of a large universal research microscope for this purpose. With this instrument, it has been possible to obtain distribution profiles for particles deposited on plant leaf surfaces.

Studies are under way to relate the fine structure of the deposit, as determined with the aid of a Flying-Spot Particle Analyzer, to the structures of the distribution profiles. Cooperative work with the Ohio Center dealt with the diffusion of colloidal particles in an electric field when suspended in turbulent flowing water. Instrumentation was developed for measuring particle concentration profiles, and turbulence measurements were made with the aid of a Hot-film Anemometer.

Studies on the turbulent dispersion of particles in air are dealing specifically with movement of particles in turbulent boundary layers and in situations where initial particle velocity is not negligible.

B. Soil Fumigation.

1. Several fungicides were applied to the soil in a sugar beet planting, in research cooperative with the Ohio Center. Some of these also received a covering of liquid wax mulch. Stands in plots treated with Captan or Arasan or Lanstan plus PCNB and mulches were all increased over 80 percent above the average check stand. The increased growth was readily observed as late as July 1.

Two of several soil treatments for control of Verticillium wilt of vegetables gave a substantial increase in yield of muskmelon, potatoes, okra, tomatoes, peppers, and eggplant. The materials used were the fumigants chloropicrin and Trizone.

A series of vegetable plots which have received the same soil treatment for nine years showed bromine injury from two compounds. Onion seedlings only lived 2 to 3 weeks or failed to develop bulbs. Potatoes failed to develop the usual number of sprouts or the plants failed to develop. Lettuce and carrot plants were also smaller in these plots. These same compounds have given the best control of root-knot nematode.

Residue analysis from turnips, sugar beets, sweet potatoes, rutabaga, radishes, potatoes, and red beets grown in soil treated with aldrin or with dieldrin, each at 2-and 3-pound-per-acre rates showed residue below allowable tolerance. The residue tolerance was exceeded in carrots for aldrin when applied at 3 pounds per acre for two years and for dieldrin at both 2- and 3-pound rates applied over a two-year period. Endrin applied at 3 and 6 pounds per acre to soil in which sugar beets and potatoes were grown produced above tolerance residue in all cases.

C. Insect Control in Grain.

1. Twelve granular insecticides or insecticide combinations were applied, in research cooperative with the Ohio Center, to corn plots for control of Northern Corn Rootworm within two days after the corn was planted. Where rootworm population was low, there was little increase in yield. Root damage and lodging were slight. In one plot series where the average larvae

population was twelve per plant in untreated corn, five insecticides (N2790, carbophenothion, GC 4072, dieldrin, Parahep) reduced lodging and produced higher yields (increase 18-34 bushel per acre).

An outbreak of chinch bug on corn occurred in June, in Ohio. Granular phorate (Thimet), sprays of malathion, and dimethoate were applied for experimental control. Phorate produced excellent control and either of the other two materials could be used for emergency control but some reinfestation could be expected to occur.

Field plot screening tests were continued, in cooperation with the Iowa station, for first and second brood borer control using both the liquid and granular formulations of a number of experimental and commercially available compounds. Although the organo-phosphates are somewhat more dangerous to apply, borer control obtained with such compounds as Parathion, Diazinon, etc., was equivalent to that obtained with DDT. The plot application equipment developed for the corn borer work was able to handle the materials without any serious problems. Conventional sprayers and granular applicators were modified and mounted on high-clearance equipment for this work. It is apparent that additional safety measures and possibly equipment changes will be needed for handling the more toxic compounds.

Studies were continued on the use of systemic insecticides for controlling first-generation corn borer larvae in corn. Four compounds, American Cyanimid 47470, General Chemical 6506, Union Carbide 21149, and Thiochron were used in these studies. These compounds were applied in the granular form at planting time, with the fertilizer, with the seed, two inches to the side of the seed, and two inches to the side and two inches below the seed. Some of these compounds were also applied at the base of the plant during first cultivation. Of the compounds tested, only #47470 gave effective control. The differences in control among the various placements tried were not very large. However, there was some indication that the chemicals applied with the seed caused some phytotoxicity and that placement two inches to the side and below the seed gave slightly poorer control. The systemics applied at cultivation time were not quite as effective as those applied at planting time. Equipment for applying these compounds was designed, developed, constructed, and calibrated specifically for these studies.

A series of tests were conducted on the use of granular insecticides to control both the first-generation corn borer and the corn rootworm. A total of nine experiments were conducted in seven locations in the western part of Iowa. Parathion, diazinon, Thimet and DDT were the compounds used. All fields were treated twice. The first application was made when evidence of rootworm feeding was found. The second application was made one week later. In one experiment, four levels of soil coverage were tried. These levels were one-half inch, one and a half inches, two and one-half inches, and three and one-half inches. In two of the experiments no cultivation was compared with the cultivation that resulted in a two and one-half inch soil coverage. The results show excellent control of both the corn borers

and the rootworms when the organo-phosphates were used. DDT gave excellent control of corn borers but inadequate control of rootworms. Diazinon gave slightly better control than the other compounds. The differences in control among the different levels of soil coverage were not large enough for significance, indicating a lack of importance for specific amounts of soil coverage level. The comparisons of cultivating and not cultivating showed some improvement where the chemicals were cultivated in; however, this improvement did not occur when moderate to heavy amounts of rain fell shortly after application. The differences were quite large and in favor of incorporation under dry conditions. These results indicate that both rootworms and borers can be controlled with one chemical.

Low volume applications of malathion with aircraft using the mini-spin nozzle and conventional flat fan-type nozzles were studied for controlling first-generation borers. A series of applications were made at four day intervals at three different locations. In addition to borer counts to evaluate control, spray droplets were collected on glass plates to study the spray droplet distributions. Borer control, as indicated by borer and cavity counts, showed little or no control with any of the low volume applications of malathion. The mini-spin nozzle produced fewer large droplets than the conventional fan-type nozzle. However, there was excessive drift with both nozzle types. In one instance, with a crosswind of less than five miles an hour, the spray swath shifted in the direction of the wind more than 100 feet. These results indicate very little if any potential for low volume aircraft applications of compounds like malathion for controlling corn borers.

Granular, emulsifiable, and in-capsule formulations of bacillus thuringiensis were applied for first-generation borer control. Results showed excellent borer control. These materials were applied with the field plot equipment used for the insecticide work. There were some problems with the emulsifiable formulations staying in suspension and with the flowability of the granular formulations. It appeared that some minor changes in the formulation processes would eliminate most of these problems and that the conventional insecticide application equipment could be used to make these applications.

2. A study was made in Georgia to develop equipment for applying either technical or concentrated materials at extremely low volumes. A low volume sprayer was designed and built which used either a flat-fan type or a pneumatic nozzle. The flat-fan type nozzle applied one quart per acre and the pneumatic nozzle applied one pint per acre. Results from these tests shows a significant difference between treatments; however, neither treatment gave adequate insect control when the equipment was operated with one nozzle above the middle of two rows. The equipment was redesigned and the nozzle was placed equi-distance between the rows at ear height. These changes were made too late in the growing season to adequately evaluate the the equipment. This sprayer appears suitable for applying low volume insecticides for grain or other crops where low volume applications may be effective.

A test was made in Georgia to determine whether insecticide and application procedures generally recommended for corn earworm control were adequate on late planted sweet corn. Three plots were used in this series of tests. One plot was treated every day, another every second day, and another every third day. Data from these tests showed that plots treated every day, every second day, and every third day had 41.7, 21.6 and 0.03 percent undamaged ears, respectively. The more frequent treatment was helpful in preventing insect damage, but none of the treatments gave satisfactory insect protection on this corn.

3. Several new methods were tried in Georgia for repelling corn earworms without the use of insecticides. Methods tried included: the use of vapor type street lighting lamps, and the use of high frequency sound. However, no control was obtained by the methods tried.

Corn was planted in Georgia with the seeds oriented with respect to the direction of the row, to study the effect on leaf distribution and consequently the effectiveness of spraying. While there was some difference in the leaf distribution because of orientation of the seeds while planting, there was no significant difference in insect control or yield.

D. Weed Control in Corn and Soybeans.

1. Field studies were continued, in cooperation with the Missouri station, to evaluate different methods and equipment for directed applications of dalapon (one and two pounds per acre) for weed control in corn. The directed applications were made so that various methods of corn leaf protection could be evaluated. This protection varied from no leaf protection to a maximum protection provided by tying the leaves to the corn stalk. A special shield leaf lifter, wire leaf lifter, and directed nozzles were used on the sprayer. Applications were made under weed-free conditions so corn damage from contact with the dalapon could be evaluated. No significant damage due to any of the treatments was found. Corn stand and yield were not reduced when dalapon was directed onto the lower three to four inches of the corn stalk. The corn was allowed to grow more prior to application than in previous years which could account for some of the resistance to dalapon injury. It was first thought that injury was found in previous years when rainfall occurred after application, but this year 1.12 inches of rainfall occurred during the week after application. It has been determined from the four years of study that the wire type leaf lifter is satisfactory for application of dalapon in corn.

Field studies were continued to determine the effectiveness of 8-, 10-, 12-, 14-, and 16 inch band applications of 2,4-D (one pound per acre), simazine (two pounds per acre), and atrazine (two pounds per acre) for weed control in corn. Herbicides applied in narrow bands result in a significant reduction in applied chemical. There was no significant reduction in corn yield due to decreasing the band width. No lateral movement of the herbicide was observed so weed control was limited to the applied area again

this year. Better overall weed control was obtained when the herbicides were applied in wider bands. This study will be continued another year.

Field studies were continued to determine the effectiveness of 8-, 10-, 12-, 14-, and 16 inch band applications of amiben (two pounds per acre) and Na-PC (sodium salt, 20 pounds per acre) for weed control in soybeans. The narrow band widths had a greater number of weeds though not enough to reduce the soybean yields. Very little lateral movement of the herbicide was observed for any of the band widths.

Studies on weed control equipment and practices for narrow-row corn and soybean production, in cooperation with the Iowa station, indicate that the equipment and systems now used for conventional row spacing will give satisfactory weed control. These studies indicate a need for changing the cultivator sweep spacings for mechanical control and for changing the nozzle and granular spreading device spacings for chemical control. Earlier soil shading with the narrow rows resulted in over-all improved weed control at the end of the season.

Studies were continued on the evaluation of smoothing operations after planting and shallow cultivations with high-speed tools. Smoothing operations evaluated were spike-tooth harrowing after planting, strip smoothing with a dragging hoe after planting, and no smoothing after planting. Early shallow cultivation practices included rotary hoeing, strip tillage over the row with a dragging hoe, and no early cultivation. Althoug the stand reduction was not exactly reflected in yields, smoothing operation directly following planting tended to reduce stands. The stand reduction was highly significant where the strip dragging hoe was used. Harrowing after planting did result in slightly better weed control. Using the rotary hoe or dragging hoe early and following this with one cultivation gave bette weed control than two cultivations alone. Additional operations with the shallow cultivating tools did not improve the weed control obtained and tended to further reduce stands. This was particularly true where the dragging hoe was used. The results of this test indicate an increase in effectiveness of shallow cultivating tools if corn land is smoothed with a tool such as a drag harrow directly following planting. Timeliness of cultivation and proper adjustment of cultivator tools appear to be more effective for controlling weeds in corn than the selection of a particular practice or cultivating tool.

In conjunction with some of the tillage field plot studies, in Iowa, early spring herbicide applications were evaluated. Atrazine, simazine, and 2,4-D sprays were applied on sod ground in early April. With the triazine compounds it was possible to obtain satisfactory weed control with only one mechanical cultivation. With the 2,4-D sprays, it was necessary to perform the normal mechanical cultivation series in order to control weeds. During the past several years, these early spring applications of atrazine and simazine have given more consistent results in terms of weed control than any other type or time of application.

2. Field studies were continued, in cooperation with the Missouri station, to compare the effectiveness of four methods of shallow (above the seed) incorporation of amiben (one and two pounds per acre) and trifluralin (one pound per acre) for weed control in soybeans. The rotary hoe, Atkins-Phelps Mix-A-Product, power rotary cultivator, and Gandy Ro-Wheel were used to incorporate the herbicides after the soybeans were planted. Amiben applied at two pounds per acre and trifluralin applied at one pound per acre gave much better weed control than amiben applied at one pound per acre. In most of the treatments, incorporation did not increase weed control; and in some of the treatments, weed population was increased over nonincorporated treatments. These results show that there is no particular advantage of incorporation with this equipment and for these herbicides.

Field studies were initiated, in cooperation with the Missouri station, to further study methods and equipment for incorporation of herbicides prior to planting soybeans. The power rotary cultivator, Atkins-Phelps Mix-A-Product, and the disk harrow were used to incorporate trifluralin (one pound per acre) and amiben (one and two pounds per acre) in field plots in Mexico silt loam soil. All incorporation was done at an operating depth of four inches. The herbicides were applied just ahead of the incorporation equipment. Some differences in results were obtained due to the herbicide that was used but not because of the incorporation treatment. The soybean yields were the same for all incorporation treatments and for those plots that did not receive the incorporation treatments. Early field notes indicated that the incorporation increased the effectiveness of the trifluralin more than it did for the amiben.

Laboratory studies were initiated in Missouri to study the possible use of ultra low volume (.1 to 5 GPA) preemergence applications of herbicides for weed control in row crops. Initial work this year has been done to study the relationship between droplet size distribution, area covered, and volume distribution of small fan and industrial atomizing nozzles. Droplet size distribution and area data were obtained by photographing droplets collected on Scotchprint paper and Lusterkote cards. The photograph negatives were analyzed on a flying-spot particle analyzer. Volume distribution data was obtained by using a fluorescent, dye tracer method of analysis. The data will be analyzed during the next year to determine some of the characteristic spray patterns that can be obtained when using these nozzles for low volume application.

To study soil incorporation of herbicides for weed control in corn, in cooperation with the Iowa station, the following chemicals were used at recommended rates: (1) Feniben, (2) Ramrod, (3) atrazine, (4) 2,4-D, (5) Randox, and (6) Randox T. These compounds were applied five to ten days prior to planting and directly following planting. Both the liquid and the granular formulations were used. The pre-plant soil incorporation methods included strip rotary tillage, tandem disking, and no incorporation. The post-plant soil incorporation methods included strip rotary tillage, dragging hoe, and no incorporation. The check plots that received no

chemical did receive the soil incorporation treatments. All chemicals resulted in better weed control than the cultivated checks. There were no significant differences in weed control, stands, or yields among the various chemicals used. Soil incorporation did not materially improve weed control, and when done after planting tended to reduce the stands and yields. The strip rotary tiller caused the greatest stand reduction when performed after planting. The spray and granular formulations performed equally well.

Chemicals used in Iowa to study soil incorporation of preemergence herbicides for weed control in soybeans included Treflan liquid, Treflan granules, Ramrod granules, amiben liquids, and amiben granules. These compounds were applied at recommended rates, and soil incorporation treatments included power rotary strip tillage before planting, disking and harrowing before planting, harrowing after planting, and no incorporation. All chemically treated plots received one mechanical cultivation. The untreated check plots were rotary hoed and cultivated once. All chemicals gave good early weed control. However, timely rotary hoeing gave equal or superior weed control to that received with the chemicals. Soil incorporation with a spike-tooth harrow after planting resulted in slightly better weed control than soil incorporation before planting. Surviving weeds as indicated by weed weights obtained in August, and soybean yield data showed that the weed control and yields were not materially improved where chemicals were used.

Field scale studies were conducted in Iowa on soil incorporation with planter attachments using Ramrod, 2,4-D, Feniben, and amiben granules for weed control in corn. All compounds were applied in 14-inch bands at planting time with and without soil incorporation. Amiben granules resulted in some corn damage when incorporated; however, this damage did not have a serious effect on yields. Results indicate little or no advantage for soil incorporation of these compounds.

E. Pest Control Equipment for Cotton.

1. At Lubbock, Texas, preemergence chemicals gave more satisfactory weed control when applied to cotton planted on beds than when applied to cotton planted in the lister furrow. Hand hoeing was significantly reduced in four-inch row cotton by the use of a post-emergence spray of Diuron plus a surfactant. Laboratory studies of nozzles' results at Auburn showed no difference in weed control when the volume of water mixed with a constant amount of trifluralin was varied from 7-1/2 to 45 gallons per acre (broadcast basis).

At Stoneville, Mississippi, a spray nozzle research bench for rapid determination of nozzle volume and spray distribution patterns was designed and constructed. The bench is equipped with special motor-driven tanks and timer and is capable of calibrating four nozzles simultaneously. The

spray pattern unit utilizes segmented filter paper strips and a fluorescent dye in the pattern determinations. A technique for subsurface chemical distribution will be added in 1966.

A rotary disc device was developed at State College, Mississippi, for ground application of ultra-low volume pesticides. It consists of two rotating discs powered by a small electric motor, and a metering nozzle. One applicator was positioned over each row and used in comparison with a mist blower ultra-low volume applicator. No significant differences in insect control were observed between the two application devices. Both gave equivalent particle deposition within the plant but the rotary disc device gave more uniform coverage across the swath with less drift.

2. Chemical weed control equipment studies continued in Mississippi in basic and applied research on soil incorporation and subsurface application of herbicides. The dye extraction technique used in evaluating the incorporation of chemicals in the soil was further refined at Stoneville. A template was designed to take horizontal soil samples within the profile. Dye was extracted with an 80 percent MOH-and-water mixture, and the dye level was determined fluorometrically. A rotavator was modified and used as an incorporator at a speed of four miles per hour. Rotor speeds of 177, 226, and 356 rpm were compared and the Rotavator gave essentially the same pattern of incorporation, regardless of rotor speed. Similarly, under closely controlled conditions at Shafter, relative velocity of rotor blade had no effect on depth of incorporation over the normal operating range. Depth of incorporation was found to be influenced more by rotor design and the rotor-to-soil geometry.

For basic studies of soil-incorporating rotary cultivators at Shafter, California, new instrumentation was designed to (1) control rotor speed, (2) control tool working depth, and (3) measure average draft. Energy required for rotary cultivators was found to increase with the relative velocity of the rotor blades and with the soil-to-rotor geometry.

Depth of incorporation of trifluralin on sandy loam soil was studied again at Auburn, Alabama, and Stoneville, Mississippi. Results were similar to last year in that depths of incorporation from one half to four inches deep at Stoneville and one inch to five inches deep at Auburn had no significant effect on weed control nor cotton plant stands and yield. Observations of root pruning with trifluralin were made possible by development of a glass-sided box installed in the treated plots at Stoneville. Several types of incorporators were evaluated on heavy clay soils at Stoneville using trifluralin and prometrine on cotton and trifluralin and vernolate on soybeans. In cotton, trifluralin gave better weed control than prometrine, but not significantly better than surface-applied monuron. Best residual weed control was observed with trifluralin. First year at Auburn indicated that a more uniform spray distribution was obtained from flooding type nozzles on a low bed type of row profile than when spraying on a flat row profile.

In a study of injection of herbicides in heavy clay soils, the application of EPTC (ethyl N, N-diproplythiolcarbamate) in clay soil with the vertical knife injector gave equally as good weed control as the horizontal blade applicator at Stoneville. Injury to cotton was not sustained, even when applied at approximately ten times the recommended rate.

In skip-row weed control equipment work, the injection of three different herbicides with 24-inch applicator sweeps on a high-and-wide machine provided uniform weed control in the skipped rows of skip-row cotton. Best results were obtained with trifluralin at 0.75 pound per acre and a mixture of one pound EPTC and 0.5 pound of trifluralin per acre.

Deep placement of nematocides at Shafter, California, did not give the superior results obtained in previous years. This is possibly explained by the fact that several rains occurred immediately after application of the treatments, which possibly sealed the fumigant into the soil in all treatments.

3. In boll weevil control, work was continued with ENT at the Boll Weevil Research Laboratory at State College, Mississippi. The flail machine for destroying fallen cotton squares was modified to improve the pick-up efficiency. The mean pick-up efficiency for the season was 88.1 percent. Soil moisture and roughness was found to have a significant effect on pick-up efficiency. Of the immature boll weevils in squares, 94.8 percent of those that passed through the machine were killed by the flail. Although the adult boll weevil population and number of punctured squares were higher in fields treated with the flail machine than in fields treated with recommended insecticides, in only one field did the egg punctured squares exceed the 10 percent recommended starting point for applying insecticides.

4. In May 1965, an agricultural engineer was transferred to Stoneville, Mississippi, into temporary quarters, preparatory to the establishment of a weed control laboratory there. He has helped in planning the laboratory facilities, has purchased part of the equipment to be used and is planning and beginning an investigations program on equipment for weed control. Congress has provided funds for a weed-insect-cotton physiology laboratory at Stoneville, which is now in the advanced planning stage.

F. Insect and Disease Control by Ground Equipment in Vegetables and Other Low-growing Crops.

1. Radishes and turnips were planted with an initial application of one pound actual insecticide per acre in the seed row, in experiments cooperative with the Ohio Center. Fourteen different insecticide treatments were made. Seedlings were later given a drench spray of the same insecticide on a two-inch width in the row at the same dosage rate. Satisfactory commercial control of cabbage maggots was obtained on these vegetables with four of the

insecticides (Bayer 25141, GC4072, Bayer 37289, VC 13). No phytotoxicity was evident in any of the treatments. Four of the treatments (Bayer 25141, Zinophos, Thimet, Di-Syston), also reduced the turnip aphid infestations to a very low population.

Cabbage, turnips, potatoes, peppers, and eggplant were treated in Ohio with ultra low volume malathion at application rates of 8, 16, and 24 oz. per acre using a sprayer fitted with compressed air atomizing nozzles, mircometer valves, and a special insecticide container to stabilize insecticide temperature. Potato leaf hopper and potato flea beetle were controlled equally well by this spray equipment applying ULV malathion in comparison with the conventional hydraulic spray equipment applying emulsifiable malathion. Control of pests (imported cabbage worm, turnip aphid, two-spotted mite, green peach aphid), on the other vegetables was either poor for applications by both types of equipment or the ULV malathion applications did not achieve control equal to the ordinary hydraulic spray applications.

G. Insect and Disease Control by Ground Equipment to Fruit.

1. A research project is getting underway at Yakima, Washington, in cooperation with ENT. In January 1966, the shell of a shop and laboratory building was completed under contract. The building is 40 ft. wide by 60 ft. long, and is of sheet metal construction on a concrete floor slab. Addition of an insulation lining, electric wiring, plumbing, a heating system, and partitioning for lavatory and an office at one end have been completed and the building is now in use.

An agricultural engineer was transferred to this project in September 1965. Some of the shop equipment has been ordered and delivered. Machines for separating codling moth pupae by size for sex, and by color for stage of pupation are under development for cooperative use with entomologists. The color separation machine uses a filtered photoelectric cell for the separation.

H. Aircraft Equipment for Application of Pesticides to Vegetables and Other Low-growing Crops.

1. In cooperation with the Ohio Center, measurements of spray deposits on corn made by spray equipment attached to a Bell 47 D-1 helicopter were made at flight speeds of 30 and 57 mph. Helicopter skids were three to five feet above the corn. A swath of 39 feet was used. About 50 percent of the top corn leaf area had deposits of more than five gallons per acre at 30 mph. At 57 mph only 19 percent of the top leaf area received a comparable deposit. About 86 percent of under leaf area received a 0 to 1 gallon per acre deposit at 30 mph and only about 62 percent of under leaf area received a similar deposit at 57 mph. These data indicate both spray deposit and spray penetration of the foliage of this crop decreased as application speeds of this spray applicator increased.

Spraying investigations with rotary wing aircraft in the Northwest showed that the narrowest effective swaths were obtained from forward mounted booms. Pronounced outboard peaking of spray deposit due to effects of the rotor tip vortex was found with the 48-foot boom. The mid and aft mounted 28-foot booms produced wider effective swaths than the same length boom mounted forward. The most uniform distribution of spray deposit right and left of the flight centerline using the 28-foot boom was obtained with the aft mounted boom. The characteristic low deposit zone right of center found with the front and mid mounted boom was not evident in the pattern curves for the aft mounted boom. The effective swath width when using the 28-foot boom was approximately 15 feet wider for the rear mounting and 18 feet wider for the mid mounted boom than obtained with the front mounted boom. An increase in application height of approximately 10 feet (from 8-10 feet to 20-25 feet) increased the effective swath width about six to eight feet for front and rear boom mountings. Changing boom length from 28 feet to 48 feet increased the effective swath width about an equal distance. The uniformity of deposit across the swath increases as the flight speed increases for all three boom locations.

A marking system using a helicopter was developed in cooperation with the Insect and Disease Control Branch, Division of Timber Management, Pacific Northwest Region, U. S. Forest Service, Portland, Oregon. The system was developed for use in forestry marking techniques, however, it may be applied to other uses.

A low-volume spray distribution system was developed for the government-owned aircraft. This unit consisted of an air tank, valve and gauge, connected by a base to a regulator valve on a liquid supply tank. An electric on-and-off valve controlled the flow of insecticide to six diaphragm nozzles with 6501 flat spray tips to obtain discharge rates at 8 to 12 oz. per acre. This unit could be mounted into either the fixed or rotary wing aircraft.

A spinning nozzle was developed based on the principle of the Mini-spin nozzle developed by Plant Pest Control Division. The nozzle developed here, however, is turned by a small electric motor instead of by airflow. No testing of this nozzle has been accomplished at this time.

2. In Mississippi, through a contract with Mississippi State University, a positive metering system for distributing solids from aircraft has been developed which has a capacity up to 50 pounds per second, independent of the quantity of material in the hopper. Another device has been developed to measure the instantaneous rate of flow of solid material from the aircraft, so that the pilot can adjust the flow without having to recalibrate the system.

I. Aerial Spray Equipment for Forest Insect Control.

1. A spray charging device, or "electrostatic spinner", was designed and constructed at Beltsville, in cooperation with the Forest Service, for studying the possibilities of electrostatically charged sprays when applied by aircraft. Advantages that might be expected included: some degree of control of atomization, a higher percentage of spray deposited on the foliage, and a more uniform spray deposit across the swath.

An electrostatic spinner was constructed which had a water flow rate of 1-1/4 gallons per minute at 15 p.s.i. Under laboratory testing the spinner appeared to be very effective in charging the spray. This was apparent when observing the spray being attracted to nearby grounded surfaces. For field studies, four spinners were made and mounted on a Piper Pawnee airplane. Repetitive spray passes were made over a spray charge sampling station and the effects recorded. Both positively and negatively charged sprays could be produced as indicated by the spray charge sampling equipment.

Atomization studies were made at Beltsville in cooperation with the Forest Service, on the "minispin" nozzles developed by the Plant Pest Control Division for the application of ultra low volume malathion (3 to 16 ounces per acre) by aircraft. The atomization produced by minispin rotary units at three speeds - 4,000, 6,000, and 8,000 rpm - was compared to that produced by three flat spray nozzles - Nos. 8,002, 80,015, and 800,067. All were used on an airplane at 95 to 100 mph air speed and 40 psi spray pressure. Mass median diameter of the spray ranged from 120 microns with the minispin at 8,000 rpm, to 269 with the 8,002 nozzles. The minispin produced a lower percentage of both the fine drops and the coarse drops than did the 800,067 nozzles. The degree of atomization influences the distribution of the spray across a swath, as well as its loss due to evaporation, drift, and convection. Small drops can move laterally from an airplane to improve uniformity of the distribution - they may also increase the drift hazard. Large drops tend to fall rapidly in a vertical direction and may cause overdosing and uneven distribution.

J. Equipment for Brush Defoliation.

1. Research on the detection and measurement of factors affecting spray distribution through a dense tropical forest canopy is being conducted on a mountainous ridge near Maricao, Puerto Rico. This work is in cooperation with CR for the Department of Defense. A spray cart covering a 30 foot swath moving along cables suspended above the forest canopy from towers is used to distribute dye-tracer spray material. Samples of spray are collected on cards located in the foliage of the forest. Varying cart speeds, nozzle design and spacing, boom pressures, weather conditions and other factors affecting the penetration of the spray material through the forest canopy are considered. An automatic weather station records air temperature, dew point, wind velocity, wind direction and rainfall. All

equipment is ready and an extensive test program is now under way involving cart speed, nozzle size, spacing and design, spray pressures, types of spray materials and other factors that affect the penetration of material through a dense leafy forest.

Investigations were made in Texas in cooperation with CR for the Department of Defense on the factors affecting the atomization of aerially applied sprays and to attempt to develop techniques for regulating droplet size. Samples of spray atomization were obtained in a low-speed wind tunnel through the use of high-speed single-flash photography. The effects of airspeed, physical properties of the spray material, physical dimensions and shape of the nozzle or other atomizing device, angle of introduction of spray into the airstream, nozzle pressure, and other factors were considered. Preliminary photographs have been obtained of several high-viscosity spray materials and water spray. A considerable difference in the method of spray drop formation has been noted from photographs of different viscosity spray materials formed with the same type of pressure nozzle. Evaluation of a series of photographs of water spray formed with two spray pressures has provided drop-size distribution data from sampling zones located three different distances from the spray nozzle orifice.

Field tests were made in Texas to measure the penetration of aerially applied spray through foliage canopies. Quantitative measurements were obtained by collecting dyed spray deposits on 4 in. x 4 in. square Mylar plastic sheets supported above and below the canopies of 10 to 12 foot tall mesquite trees. Approximately 46 percent of an invert emulsion spray applied at the rate of 7.24 gallons per acre and 60 percent of a conventional oil-water emulsion spray applied at the rate of 2.09 gallons per acre penetrated the mesquite canopy. In similar tests with live oak trees which were 10 to 15 feet tall only 12 percent of a water spray applied at the rate of 2.18 gallons per acre penetrated the foliage canopy. A spray penetration sampling station was constructed to measure and compare the penetration of various sprays through a dense 40 foot tall post oak overstory canopy and a dense 15 foot tall yaupon understory canopy. In initial tests 21 percent of a water spray applied at the rate of 3.43 gallons per acre penetrated the oak canopy and only six percent penetrated both the oak and yaupon canopies. Samples collected under 20 to 35 foot tall winged elm trees indicated that approximately 57 percent of a 3.9 gallons per acre application of particulated spray (Norbak) and approximately 43 percent of a 3.4 gallons per acre application of conventional water spray penetrated the foliage canopy. Aerial spray distribution measurements indicated that conventional water sprays and oil-water emulsion sprays were distributed more uniformly within the swath than were invert emulsion sprays or particulated sprays.

K. Foreign Research Under Public Law 480 Funds.

1. In September 1964, a three-year research contract was awarded the Agricultural Research Station, Beit Dagan, Israel, to improve the

penetration of insecticide spraying into the dense foliage citrus trees. Some aerodynamic studies of the vortex air jet were made in 1965 in the laboratory, and a report has been prepared containing a theoretical analysis of these laboratory studies: "Experimental and Theoretical Study of Turbulent Swirling Jets Issuing from a Round Orifice", by Nehemiah Chigier and Amnon Chervinsky, TAE Report No. 46, November 1965, 28 pages and 10 figures.

The chief purpose of the field experiments during 1965 was the establishment of a measure of performance of various existing spraying methods, in order to be able to compare them later on with a vortex air jet sprayer. One of the criteria was the determination of the depth of penetration by assessment of the spray deposit on cards. Actual tests of pest control should be included in the experiments to make the results more reliable. Some species of the armoured scales, which are the most serious pests in citrus plantations were considered but the effect of the application is very slow, and results are obtained only after three to six weeks by repeating the counts. A third criterion was taken into consideration. After harvesting, the fruits of whole test plots were graded according to their degree of contamination with scales. This additional information gave significant results in some of the tests.

The following spray equipment was used: a high-pressure sprayer with vertical boom and oscillating nozzles; an air-blast sprayer with axial flow fan and a slot around its periphery as air outlet ("speed sprayer"), delivering the air to both sides; the same sprayer, but with a hood which delivered all the air to a slot, directed to only one side; the same sprayer with the one-sided slot, and with oscillating vanes in it; an air-blast sprayer with axial flow fan, one-sided air slot, oscillating vanes and equipped with a compressor to deliver air at high pressure to atomizing nozzles, for low-volume mist spraying. Hand spraying with a spray gun at high pressure and high volume was taken as the check in most of the experiments and proved to be the most reliable method, at least under experimental conditions.

In the depth of penetration tests it was found that with the high-volume air-blast sprayers, coarse sprays penetrated significantly deeper than did the fine sprays. Changes in forward speed, on the other hand, had less influence on the depth of penetration, provided that the application rate was held constant. Application rate had to be somewhat higher with the automatic sprayers than with the spray guns. With regard to quality of coverage it was found in former investigations that at least part of the droplet spectrum should contain coarser drops in order to achieve good coverage of the fruits. In some species of orange and lemon trees, pest control with the high-volume air-blast sprayers and the vertical boom sprayer was satisfactory. In dense foliage orange trees and in grapefruit plantations results with the vertical boom sprayer were poor, with the

high-volume air-blast sprayers somewhat better, and with the hand spray guns the best. The effect on pest control of the low-volume mist sprayer with air compressor was negligible. The tests will be continued and an experimental vortex air jet sprayer will be included.

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AREA 4: CROP HARVESTING AND HANDLING OPERATIONS AND EQUIPMENT

Problem. This area is concerned with the development of equipment and methods for efficiently harvesting crops and for handling of farm crops, with emphasis on the preservation of inherent qualities during these processes. The cost of harvesting and farm handling of most crops is the major expense of production, often amounting to over half of the total returns to the producer from the sale of the product. In addition, supply and adequacy of manpower for these operations are becoming progressively less satisfactory.

While research on harvesting equipment and methods has led to much improvement in the reduction of production costs of such crops as grains and forage, much additional work needs to be undertaken, both basic and developmental, in order that all crops may be mechanically handled. Harvesting equipment research for fruits, relatively recently initiated, has already resulted in sizable cost reductions, but the potential savings for these crops and vegetables are enormous. Tobacco requiring over 400 man-hours per acre currently, also has long needed mechanization.

The problems associated with harvesting and handling are interrelated with crop growing, processing, and storage thus necessitating close cooperation with engineers in other research areas and with scientists in other disciplines.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of crop harvesting and handling. Citrus fruit harvesting research is being conducted at Lake Alfred, Florida; Davis and Riverside, California; in cooperation with the respective State Experiment Stations. Equipment for cotton harvesting is under study at State College and Stoneville, Mississippi; Auburn, Alabama; Lubbock, Texas; and Shafter, California; in cooperation with USDA Cotton Ginning Laboratories and the respective Experiment Stations. Research on deciduous fruit harvesting equipment at East Lansing, Michigan; Wenatchee, Washington; and Davis, California; is cooperative with the Experiment Stations in those States, and with producers, and machinery manufacturers. Crops under study include: Apples, pears, peaches, apricots plums, grapes, blueberries, cherries, and dates. Research on mechanical coffee harvesting is conducted in cooperation with the Hawaii Experiment Station. Development of new techniques for harvesting forage is underway at Beltsville, Maryland, and at Tifton, Georgia, in cooperation with the Georgi Experiment Station. Research on forage seed harvesting is underway at Corvallis, Oregon, in cooperation with the Oregon Experiment Station, farmers, and industry. Research on oilseeds and peanut harvesting equipment and methods is cooperative with the Experiment Stations at Bogalusa,

Louisiana (tung nut); Holland, Virginia (peanuts); and Tifton, Georgia (peanuts). Potato harvesting research, cooperative with the Red River Valley Potato Growers' Association, is being conducted at East Grand Forks, Minnesota. Equipment and methods for harvesting sugarcane are under study at Houma, Louisiana, in cooperation with the American Sugar Cane League; and in Belle Glade, Florida, in cooperation with the Florida Experiment Station. Tobacco harvesting research is conducted cooperatively with the Experiment Station at Lexington, Kentucky.

A 3-year contract is underway at Louisiana State University for research on mechanically removing tops and leaf trash from sugarcane. Contracts have also been initiated at Virginia Polytechnic Institute for study of equipment and methods for farm curing and drying of Virginia-type peanuts and at the Georgia Coastal Plain Experiment Station for determination of location, nature and extent of losses and damage occurring in peanut harvesting and farm handling. A research contract was continued with Clemson, Texas A. & M. and Mississippi State University to determine the effect of mechanical harvesting, handling and ginning on the germination of cottonseed.

The Federal engineering effort devoted to research in this area totals 24.8 scientific man-years. Of this number 4.0 is devoted to citrus; 3.9 to cotton; 7.5 to deciduous fruit; 0.8 to forage; 1.5 to forage seed; 1.8 to oilseeds and peanuts; 2.0 to potatoes; 2.0 to sugarcane; 1.0 to tobacco and 0.7 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Most of the state agricultural experiment stations are engaged in some aspect of basic or applied research which is concerned with improving machines and methods for efficient harvesting and farm handling of the many economic crops which make up the total national agricultural production. Much of this research effort is cooperative with the Department.

Detailed investigations are in progress to develop reliable mechanical harvesting and handling equipment as well as ways in which improvements might be made in crop production systems to increase yields, product quality and overall efficiency.

Current research is concerned with the diverse problems involved with these specific crops: All small grains, including rice and field corn; cotton, peanuts, castor beans, and safflower; citrus, apples, peaches, olives, apricots, cherries, prunes, cranberries, coffee, grapes and pecans, green-cut forages, hay and seed crops; cabbage, lettuce, asparagus, tomatoes, Irish potatoes, sweet potatoes; blueberries, peas and sweet corn; tobacco; and sugarcane.

During the course of these engineering investigations close cooperation is maintained with research scientists who have responsibilities for making improvements to these crops. This activity is most important in order to have machines and systems that are compatible with the new developments.

A total of 34 scientific man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Citrus Harvesting Equipment

1. Harvesting citrus. The decreasing availability of suitable labor for picking citrus has created a serious need for improved methods and equipment for harvesting citrus fruits. Cooperative research with the Florida Citrus Commission and the University of Florida Citrus Experiment Station was continued with headquarters at Lake Alfred, Florida. A summary of the Florida work follows: Harvesting experiments on three varieties of orange and grapefruit continued (third season) with the tree-shaker-catch-frame system previously developed for citrus on this project. Three consecutive seasons of shaking the same trees have not significantly affected the fruit yields of early and midseason oranges and grapefruit and fruit removal was not materially affected by date of harvest. This prototype shake-catch equipment is ready for commercial use. Shaking force, phase angle, and limb displacement were measured on six limbs of different sizes. This information was used to develop a method of analytically determining the limb stroke from the limb size and readily measured tree shaker characteristics. Development work continued on the horizontal oscillating air-blast harvest method in cooperation with a large farm machinery manufacturer. Harvest trials were run for the third consecutive year with the same trees in the long-range program to study the effects of high velocity air on the tree and fruit. Seven different picking auger configurations were designed and molded in the development of a batch-type harvester for fresh fruit. Limited field trials were conducted to determine best spindle design for optimum fruit removal and minimum tree damage. One design looks very promising in that a high percentage of the fruit is removed with almost no tree damage. A three to four man platform picking aid was designed and constructed for use in tree wall plantings where the trees were shaped into 6-and 8-foot thick hedgerows. A commercial one-man positioner, which the California manufacturer claimed increased picking efficiency by several hundred percent, was tested for spot-picking tangerines. A maximum increase in harvest rate of 11.7 percent was obtained using a two-man team, one in the machine and one on the ground. Several other private industry picker positioners and fruit picking aids were observed or evaluated by project personnel. Although many were ingenious and of interest, none were developed beyond the test stage. Considerable consulting and evaluation work was done by project engineers with private inventors and manufacturers who are developing fruit harvesting machines. An expanded program of pruning for mechanical harvesting and chemical fruit abscission research was carried on under contract with the Agricultural Experiment Station of the University of Florida. Iodoacetic acid loosens Hamlin and Pineapple oranges and reduces the time to shake fruit from a tree from approximately 5 to 1 1/2 minutes.

Research in California in cooperation with the University of California, growers and manufacturers was continued with headquarters at Riverside. The summary of the California research follows: A mechanical man-positioning

aid called the Power Ladder was developed for fruit harvesting and tree pruning. Extensive tests have been made in both California and Arizona and showed that on lemons and oranges the unit increases picking efficiency from 30 to 40 percent. The machine is now being manufactured by a commercial manufacturer, and will possibly sell for under $2,000. Electro-mechanically actuated power clippers were designed and constructed to be used in conjunction with a mechanical aid such as the Power Ladder. During an average day the picker clips approximately 15,000 fruit. This unit may greatly reduce fatigue which develops in the hand of the picker during the day. The unit will be evaluated next season. Three methods of using vertical pulsating air were tested. Although neither of these units had the capacity for required air velocity, the use of vertical air looks promising and further studies will be made. An experimental catching frame for use at different levels in the tree was constructed. It consists of fins spaced 2 inches apart which can be inserted into the tree. Further tests will be made on this unit. The study of the effect of applying direct current electric power through citrus trees was continued. It was definitely shown that current affects nutrient flow and that if used properly it may cause abscission, stimulate growth, retard growth, and affect the tree in many interesting ways. This work will be continued on an expanded basis. Work continued on fruit detachment devices. A snap separation device which uses several rollers is under construction. Further development on the vacuum twisting removal units was confined to laboratory studies to determine a sock design which will work on a range of fruit sizes. Drawings have been completed and shop work started on a test bank of nine units. Work on sensing devices continued. A new model of the reflected light selector was constructed and tested using photocells. By using artificial light to illuminate the tree and fruit to a more uniform level than natural light, the new model worked satisfactorily. Possibilities of having the unit compensate for differences in natural light levels, thus eliminating the need to use artificial light, are being investigated. This selector will be used with the bank of vacuum removal units to detect and pick only ripe fruit.

Forty-two orange and grapefruit trees in major growing areas of California were surveyed for fruit location, fruit size, stem length, extent of clustering and separation force data. The orange trees were later picked and a detailed time study made of picking operations. The data have been put in a form so that it can be analyzed by a computer. Shake harvesting tests were conducted on late season Valencia and Navel oranges using an FMC limb shaker. Average removal of Valencia's was about 60 percent. About the same percentage of fruit was injured in falling through pruned trees as through unpruned trees. Approximately 3,000 fruit from each of four treatments (three shaking tests and one handpick check) were washed, treated with a fungicide, waxed and packed in shipping cartons. The percent decay for unpruned trees was twice that for pruned trees. Fruit shaken from the pruned trees had twice the decay of handpicked fruit. Percent removal from the Navel trees sprayed with 2,4-D to tighten the fruit, averaged 65 percent whereas removal from unsprayed trees averaged 80 percent. This test was performed to evaluate the effect of abscission chemicals in addition to

other factors. Fruit injury tests of Navel oranges have shown that pruning out the deadwood can reduce injury by 70 percent. There is good indication that fruit can be dropped through the lower portion of the tree and possibly from higher levels with better pruning, with no more damage than would occur in handpicking. The single clip lemon clippers reported on last year were sent to Sunkist Growers. They designed a production model clipper, using the gauging and jaw design. Several hundred of these are now in use to test commercial acceptance.

B. Cotton Harvesting Equipment

1. Topping and side-pruning 4 to 5 foot cotton at two stages during the peak fruiting period (July 23 and August 7) did not affect picking efficiency but caused a slight reduction in yield at Stoneville. Plant lodging was increased in side-pruned plots following severe wind and rainstorms in mid-September. Fiber quality was not affected by topping or side-pruning except a slight increase in grade was obtained in both the topped and side-pruned plots. Ideal weather conditions during harvest virtually eliminated the boll rot problem in 1965.

2. Sources of trash contamination were studied further under laboratory and field conditions at Stoneville. Highspeed movies of the internal action of a picker head indicated that most of the green trash that ends up in the picker basket is wrapped up in the cotton as the cotton is wound on the spindles. In an effort to remove some of this trash before it was mixed with the cotton, an experimental grill-type pressure plate was constructed and tested in both laboratory and field. Results indicated that trash removal with this device was insufficient and that removal might be accomplished better at other points in the picking unit or in the conveying system.

High-moisture weather conditions at the beginning of the 1965 harvest season caused unusually severe second-growth problems at Stoneville. Different harvest-aid chemicals ranging from desiccants to defoliants were compared with respect to the trash content and grade of machine-picked cotton. Both mature leaves and immature second growth were present when the chemicals were applied. Leaf content in seed cotton before cleaning ranged from slightly less than 1 percent for both defoliated and desiccated cotton, to a high of 5.9 percent for undefoliated cotton tramped in the trailer. Classer's grade ranged around Middling for defoliated and desiccated cotton, while the undefoliated cotton was reduced in grade because of "light spots." Harvesting cotton following a chemically-induced wilting of leaves showed no advantage over normal harvest-aid procedures at Shafter.

3. Studies of plant varietal characteristics affecting mechanical harvesting were continued at Auburn and Stoneville. Picking energy measurements of bolls from 13 varieties of the 1964 study were made and correlated with field losses at Auburn. As picking energy increased, weather loss decreased while machine loss remained fairly constant for most varieties. However,

machine loss increased for the stormproof variety with high picking energy. As picking energy increased, the total field loss decreased from a high of 20 percent for the easy-to-pick varieties, leveled off at 12 percent for the storm resistant varieties, and then increased to 15 percent for the stormproof variety. A total of 50 plant character and picker performance measurements were investigated for correlations with each other. Bolls were again collected and field data obtained for the same 13 varieties used in 1964. At Stoneville, six commercial varieties with distinct differences in stalk and boll characteristics were compared in a mechanical picker field efficiency study. Included were two western storm-resistant varieties and four popular open-boll varieties. Highest picking efficiency was obtained with the open-boll varieties, particularly those having the longest staple. However, grade of lint was slightly lower for varieties with the best picking efficiency.

Several varieties of cotton with widely different characteristics were used in a detailed study of basic factors affecting the removal of cotton from the bur. A special instrument to measure force and energy required in removing a lock of seed cotton from the bur was also designed to provide a constant removal speed and to measure interseed drag. Early results indicate that boll removal is affected by several things. These include: (1) The wrinkling or shriveling of the carpel wall as the boll opens and begins to dry actually clamps many of the fibers to the carpel wall; (2) fungus attacks on both the cotton fiber and carpel wall appears to cause the fibers to become glued to the carpel wall; (3) the number and weight of seed and type of fiber in each lock determines how much the lock expands and pushes against the carpel wall; and (4) a mucous-type substance left on the fiber as it is formed acts as a gluing agent, causing the fiber to adhere to the carpel wall when wet. Results of these basic studies will be used to determine possible effects on field losses and picking efficiency.

4. Spindle parameter studies with the laboratory model cotton picker at Auburn established a significant (.001 level) correlation coefficient (0.71) between model picker efficiency and field picker efficiency. The harvesting efficiency for spindles coming in contact with only 20 to 50 percent of the locks of a boll was 75 percent, indicating cohesive forces between locks during the picking action. The average spindle efficiencies of fluffy, weathered, and knotty bolls for 13 varieties were 93, 85, and 60 percent, respectively. Storage of bolls in the laboratory did not affect spindle efficiency. In a barb removal study, spindle efficiency of 14-barb spindles was not materially affected until the last three barbs on the tip of the spindles were removed. A 14-barb spindle had a model picker efficiency 2.2 percent greater than that of a three-barb spindle and a field picking efficiency 2.6 percent greater than a three-barb spindle.

No appreciable wear was obtained on spindle barbs after picking 70 bales in 1964 and picking efficiency as determined on the model picker was not affected. The spindles were used again in 1965 and have been removed for further study.

There was an interaction of picker drum height and plant population on picker efficiency at Auburn this year. Raising the drum 1 inch decreased picker efficiency 2.2, 2.7, 1.3, 0.8, and 0 percent for populations of 10, 20, 40, 60, and 80 thousand plants per acre, respectively. In the same order, raising the drum 3 inches decreased picker efficiency 4.4, 4.0, 1.7, 1.6, and 2.5 percent.

Similar to last year's results, different skip-row patterns did not affect picker efficiency, and five varieties had the same efficiencies in a skip-row pattern as in a solid-planted pattern.

The seed count slide rule method compared favorably with the S-2 standard procedure for evaluating harvester field efficiency.

At Lubbock, the narrow-row stripper harvester was improved by several minor design changes and performance was satisfactory in 10, 20, 27-inch row spacing and in double-row cotton. In another test, the brush-roll stripper had a higher harvesting efficiency than the steel-roll or finger-type machines.

5. A comparative test of stripper harvesting and spindle picking was conducted at Auburn in cooperation with the Southeastern Cotton Ginning Research Laboratory at Clemson. Ginning data are not available but field data indicate little difference between the two machines. The picker overall harvesting efficiency (twice-over) was 96.2 percent as compared to 95.8 percent for the stripper. The picker harvested 2,510 pounds of cotton per acre with a trash content of 4.6 percent and 2,396 pounds of clean seed cotton. The stripper harvested 3,338 pounds per acre with a trash content of 25.3 percent and 2,493 pounds of clean seed cotton.

A ground gleaner test was completed at Shafter and spinning has been completed at the Texas Tech Laboratory. Data on spinning characteristics of this cotton are being analyzed and a report will be published this year.

To facilitate cooperative work with other departments, as well as our own plot work, two major pieces of research equipment were designed and built during the year. At Lubbock, a two-row plot stripper was built to harvest small plots with a capacity of keeping separate rows separated and deposited in either bags or trailers. At Stoneville, a seedcotton scale was devised and mounted on a specially-designed two-wheel trailer to facilitate field weighing and sampling of small plots harvested with a mechanical plot-picker.

6. A handling and field storage study was initiated at Lubbock as the first step in evolving improved systems of handling machine-stripped cotton. Approximately two bales of cotton were stripped with an experimental Allis-Chalmers stripper equipped with a bur extractor. This cotton will be used to study the feasibility of baling or smaller packaging of stripped cotton for more efficient handling and field storage.

7. Cottonseed damage resulting from mechanical harvesting was studied under a contract at Clemson, South Carolina; State College, Mississippi; and College Station, Texas. Preliminary results from Clemson indicate seed damage is occurring in the picker at several points--the doffing system, conveying system, and in the basket cleaning grates. Instrumentation has been developed at State College, Mississippi, to measure the relationship of energy absorption characteristics to seed damage, and at College Station to measure the effects of harvesting and temporary storage conditions on seed quality.

C. Deciduous Fruit Harvesting Equipment

1. Orchard grading apples. Growers store millions of bushels of apples "orchard run." Last year over ten million bushels of undergrade and defective fruit were stored in CA or regular storage and then sorted out and sent to cider mills or other low return outlets. One possible way of eliminating this problem is to orchard grade. The experimental orchard grader was redesigned, and used to field grade McIntosh and Jonathon apples. Although the results are promising, one more year's data are needed before recommendations can be made.

2. Harvesting apples. Apples for fresh market must be picked without bruising the fruit and must be harvested at optimum maturity for long-time storage. Labor is not available to do this and machines and/or methods which will reduce labor are needed. A study of piece work rates of harvesting apples was made. This included picker variables such as sex, age, experience, and motivation and orchard variables such as tree size, fruit size, fruit density on the tree, weather conditions, and supervision. This work is being summarized and will be published in FY 1967. Once apples are detached from the trees they must be transferred to containers without bruising. A positive flow conveyor consisting of padded counter rotating belts was developed. It can move fruit in any direction with no possible bruising whatsoever. A high capacity bin filler is also being developed which can be used in the field to uniformly fill pallet boxes without bruising. Seven methods of distributing the fruit in the bins are under test. A mobile test machine was designed and constructed for harvesting time studies in tree wall plantings. The machine moved pickers continuously past the face of fruit tree walls. One worker picks the fruit below 5 feet and the other worker picks the fruit from the 5 to 10 foot level. The fruit is placed on conveyors and moves through a bin filler into pallet boxes. The unit was used in picking tree walls of Golden Delicious and compared to hand harvesting into a bag and carrying the fruit to the bin. Picking with the machine resulted in an increase of picking efficiency of 26 percent and also made it possible for women to do the work. Component design and construction was begun on a proposed four-picker harvesting aid for 8-foot high tree walls. Upon completion of the machine, field trials will be made. This work should be of value in planning future orchard designs for maximum efficiency. Over 40 percent of the apples produced in the United States are processed. The critical shortage of harvest labor

and the relatively low value of this fruit makes it imperative that harvest efficiency be increased. Two inertia shakers and a modified cherry fruit collecting unit were used to mechanically harvest over 800 bushels of McIntosh, Grime, and Greening apples. The apples were processed into applesauce. Results showed that the sauce was of equal quality to handpicked fruit. However, a large percentage of the apples needed trimming and this increased processing costs because the lines had to be slowed down (47 percent of the McIntosh needed trimming--only 14 percent of the Greenings needed trimming). Next year, two new machines will be constructed and tested. One unit will pick up apples off the ground. The other is a low-cost collection unit for shake harvesting. Apples will be harvested with both machines, processed into apple juice, applesauce or possibly apple slices. As a result of drop tests made last year a third test unit will be constructed. This will consist of an air pillow endless belt catching frame which will be evaluated for catching shake-harvested apples.

3. Harvesting blueberries. Although 70 percent of the Michigan cultivated blueberry crop and a high percentage of the crop in other states was harvested mechanically with batch-type equipment, which was developed on this project, there was still a harvest labor shortage. Principles for a continuous mechanical harvester were developed and two companies have made prototype units. Approximately a dozen of these units which will sell for $29,000 to $35,000 each will be evaluated in the field next season. The third year of a study on the effect on yields of how mechanical harvesting equipment is used, was completed. Results show that if the equipment is used carelessly, yields will be lowered; but if used properly, yields are about the same as those resulting from hand picking. Old blueberry bushes produced small berries and are often so tall that they are hard to harvest. Equipment was constructed to top plants at heights of 6 to 36 inches. Results achieved were disappointing in that the wood which was removed was replaced by vegetative canes which did not produce fruit and would increase harvest difficulty.

4. Harvesting tart cherries. Last year, mechanical harvesting equipment and methods which were developed on this project were used in harvesting more than 27 million pounds of tart cherries. Although the machines replaced 5,100 workers there was still a shortage of harvesting help. Average mechanical harvesting costs were $11.70 per ton as compared to $55 per ton for handpicking. Next season (1966) over 50 million pounds of tart cherries will be harvested with machines and it is important that quality of this fruit be maintained. Electronic sorters were evaluated and as a result of our findings several changes were made in the units which improved their effectiveness and capacity. Further work on destemming units was conducted. In cooperation with a grower, a successful destemming unit based on a new principle was constructed and tested. It will be commercially available in the 1966 season. A new procedure of handling mechanical harvested cherries was studied on a theoretical basis and recommendations made. Cherries will be soaked in the orchard, scheduled into the plant, run over an eliminator and destemmer before being weighed and graded. One processor plans to try

this system and it will be evaluated. During the 1965 season an instrument for measuring firmness of cherries was developed. It will be of value in research work and could be of value at grading stations and at processing plants. Research on thermal and physical properties of tart cherries was continued. Relationships for flesh density, flesh specific heat and pit weight were determined.

5. Harvesting prunes. Mechanical harvesting methods developed on this project are now being used extensively to harvest prunes in all areas of California except the Santa Clara Valley. The California Annual Farm Labor Report showed that peak labor for harvesting prunes in 1960 was 30,300 workers, in 1965 the peak labor force was 18,000 workers. A number of growers in the coastal area are using shakers for removal for hand pick up. However, most growers are still harvesting by hand in this one area and improved methods and equipment are needed. A test was conducted to evaluate the feasibility of using a helicopter for selective removal of prunes in coastal areas. Three plots were arranged to compare the effects of different forward velocities. The helicopter was flown with the blade tips over two adjacent tree rows. Data were taken of the removal force before and after, the sugar content before and of those removed, and the percentage removal. The air velocity and frequency of pulsations per tree were insufficient to obtain a desirable removal percentage and would not be a practical method for grower use. After two passes, removal was 10 percent and was considerably less than the ground level blowers test in 1962.

6. Bark damage. Thousands of trees are being harvested with tree shakers. Trees are also being modified for mechanical harvesting. Engineering properties such as strength of both bark and wood are needed to prevent bark damage in design of shaker clamps and determining methods of shaping trees. In Michigan, the composition and strength of cherry bark was determined. Maximum longitudinal and tangential strength for the inner bark tissue was about 640 and 70 pounds per inch, respectively. The outer periderm strength was about 980 and 3,250 pounds per square inch (longitudinal and tangential). Longitudinal cambium shear strength was about 30 pounds per square inch. In California, tests were initiated to study the seasonal variation in bark strength of prunes, almonds, peaches, and olives. Measurements were made of the tangential bark strength and bark moisture at five different periods throughout the year. Results indicate the weakest condition existed in late spring when reactivation of the cambium and fluid flow occurs. The bark is strongest during the winter months when there is no tree activity during dormacy. At the weakest point, strength is about one-half that of the strongest period (65 p.s.i. and 150 p.s.i.). During the time of harvest of early deciduous fruit crops, strength has increased to about half the strongest state and continues to increase into the winter. In Michigan, studies of the seasonal effects on mechanical properties of tree limbs and on the viscoelastic behavior of wood have been initiated. Research on improving limb shaker clamp design continued. The shock adsorbing feature incorporated in the belt-type clamp did not function properly because of friction between the rollers and shaft. The purpose was to limit longitudinal forces on the limb when shaking at bad angles with the limb. Another

pad was developed to have this same feature by using a thick-soft rubber in the pad to permit relative motion between the limb and the shaker longitudinally. The design combined a curved backup suface with a flat rubber face surface. This configuration permits a more uniform radial force to the limb and centering is not critical. Field tests showed this design of limiting longitudinal shear forces to have practical application. The clamp on the trunk shaker developed in 1961 was redesigned. Four hydraulic cylinders were mounted 90° apart and were closed onto the trunk simultaneously in a radial direction. Limited tests showed this design to be satisfactory. The development and testing of a shaker to attach perpendicular to limbs was continued this year by designing a powered arm for positioning the vibrator unit on the limb. The arm consists of pivoted linkages which are actuated by rotary motors or cylinders. The motions are controlled by a single control handle which, when moved in the desired direction, actuate micro-switches which energize solenoid valves and directs fluid to the actuators. Field tests demonstrated that positioning of the vibrator unit was satisfactory. The unit is more complex than the ordinary inertia shakers and consequently more costly and slower operating. Acceptance will depend on future bark injury problems.

7. Harvesting dates. Dates grow on palm trees 30 to 50 feet high and it was necessary to replace harvest labor with machines. About 65 percent of the 1965 to 1966 crop was harvested mechanically using the bunch-cut method of harvesting and bunch shakers developed on this project. It is expected that 100 percent of the crop will be mechanically harvested next season. The savings resulting from mechanical harvesting last year was about $210,000. The California Department of Employment reports that the peak labor in 1960 was 800 foreign workers and 90 local workers. The records show a peak of 160 workers this last year. This work was terminated in June 1965.

8. Pollinization of dates. All commercial date-producing areas in the world pollinate the female date blooms by some hand method. From three to six trips up the palm during the season are necessary. There is no attractant in the female bloom which will cause insects to bring pollen to it. Satisfactory pollination by air movement can usually be obtained if male palms are located in proper relation to female palms but the California plantings are not arranged in such a manner. This year's date crop averaged about 20 percent unpollinated (cull) fruit because pollination was not done at the proper time, during March and April, 1965, due to a labor shortage. The crop has a farm value of over $3,000,000 and a pack-out value of over $9,000,000. Labor aids were investigated as a method of decreasing labor requirements. The harvesting towers are not as efficient as the ladder, when used as a means of entering the palm for pollination. A pneumatic tool was designed which a worker on a harvesting tower could use to reach into the palm, open the bloom, and pollinate it. The tool was less efficient than climbing into the palm and doing the job by hand. A fixed wing and a rotary wing aircraft are now under contract and doing experimental aerial pollination work. Special equipment was designed and built for the

helicopter. Glass slides in the palms are used to catch pollen samples during the flights. Twelve blocks of 40 palms each are involved in the tests. The results of this work depend upon the results of next year's crop. It is expected that the aerial pollination work will continue for the next year or two and improvements will be made, based upon the slide evaluations and resulting crops.

9. Harvesting clingstone peaches. Although principles for mechanical harvesting clingstone peaches were developed on this project several years ago, no one has made prototype equipment. The harvesting labor supply has become serious. This project has been reactivated and prototype equipment utilizing the shake-and-catch methods are being developed and will be evaluated under commercial conditions.

10. Coffee harvesting. Coffee harvesting labor outside the farm families is practically nonexistent in Kona, Hawaii. Since harvesting accounts for over 70 percent of the total farm labor input for coffee production, the grower's income is limited by the amount of coffee the farm families can harvest. Acreage has declined sharply and mechanical harvesting methods must be developed if the industry is to survive. Research on picking aids continued. A commercially manufactured hand-held blueberry vibrator was modified to increase its effectiveness in removing ripe coffee cherries. The modified unit removes fruit rapidly, but no overall conclusion can be drawn without further field testing, including fruit collection and analysis of harvested coffee for ripeness. A privately financed experimental picking aid was field tested and evaluated. The back-carried device included a pneumatic conveyor to carry fruit from the picker's hand to the container. Harvesting rate was slower than with the conventional waist-supported collecting basket. Research on complete mass harvest systems continued. Equipment consisted of a shaker mounted on a temporary transport unit. a military jeep-mounted collecting frame, and a pneumatic conveying system. This equipment operated successfully, but more extensive field testing is required for full evaluation. Based on observations alone, more efficient operation would result if (1) the shaker was lighter in weight and would remove ripe fruit more uniformly throughout the tree, and (2) the collector frame was more maneuverable. An air-powered rotary vibration inducer manufactured commercially for use on grain and feed hoppers was tested on coffee trees. The resulting vibration was insufficient for fruit removal. Laboratory studies are underway to investigate effects of cumulative damage to the abscission points between the coffee cherries and the stem. A new shaker is under construction which will produce circular tree motion. Present collecting equipment is being modified and new equipment using a somewhat different principle is being designed. To facilitate more extensive field tests of equipment, arrangements have been made for a 0.6 acre, 300-tree orchard at the Kona Branch Station and a grower-cooperator has volunteered additional acreage. Also, a 200-tree experimental plot at Waimanalo, Oahu, Branch Station is being rejuvenated.

D. Forage Harvesting Equipment

1. Studies of the effect of methods of harvesting on processing energy requirements showed that field-wilting of Coastal bermudagrass greatly reduced the energy requirements for grinding and pelleting. The pellets produced in these studies were fed to steers and the results of feeding are not yet available. From the chemical analysis, however, it does not appear that the hay was appreciably reduced in quality by the field-wilting.

2. A new hay wafering process and the resulting product was evaluated. The wafers were formed by rolling the hay into cylindrical units. The experimental machine was small, lightweight, and simple in design. A basic problem existed in feeding the hay into the wafering device so that the latter worked properly. Unlike extrusion wafering, high moisture forage and forage consisting of grasses could be wafered by this rolling or wrapping process without the addition of moisture and with relatively low power consumption. The experimental wafers were less dense than most formed by extrusion, but equally durable. The wafered hay was not free-flowing. It could be satisfactorily dried though the wafers released moisture slowly. The rolled wafers were eaten satisfactorily by dairy cattle.

3. Significant field losses occurred from raking forage regardless of how damp the forage. The least field losses occurred by cutting and windrowing the forage in the same operation with a self-propelled windrower and handling the windrows with a windrow turner. Slightly more alfalfa was stored in a tower silo as haylage than as direct-cut silage. A slight increase in density occurred when dewatered forage was ensiled, however, the processing and ensiling losses were as great as those from ensiling direct-cut silage. The most dense silage was only about half as dense as the maximum possible if the voids could be eliminated. Storing forage as haylage resulted in the least losses.

E. Forage Seed Harvesting Equipment

1. Development of a high-speed scalper for seed crops. Several kinds of rotating scalpers were designed, constructed, and tested in an effort to develop a machine to separate straw from threshed seed in a combine. Rotating fingers, squares, and other shapes were tested, but the separating efficiency was not comparable to the present method.

2. Development of components for cutting, picking up, threshing and cleaning field seed crops. Rotary cutter tests were continued in 1965 to develop a new method of picking up seed crops for an improved-type combine. A rotary cutter, with slight alteration, was again tested in several grass and legume crops. Total seed picked up was only 39.7 percent for windrowed red clover, 42.1 percent for standing red clover, 53.1 percent for windrowed creeping red fescue, and 60.5 percent for windrowed Newport bluegrass. These results are not adequate; therefore, the machine will be completely remodeled and tested again during the coming year.

A belt thresher is being developed that will provide a more efficient threshing unit for an improved-type grass and legume combine. The experimental machine, as constructed, employs the same threshing principle as the laboratory rubber-covered rub board. Therefore, it is expected to handle difficult-to-thresh and easily-damaged seeds without injury. Unthreshed seed fed between rough surfaced belts is rubbed and rolled by the belts traveling at different speeds until the seed is threshed. Preliminary tests indicate that with proper adjustment of feed rate, belt speed, and belt pressure, crimson clover can be satisfactorily threshed.

Time-of-harvest studies were continued on bluegrass in 1965, for a fourth year, to determine the optimum mowing time as indicated by pure-live-seed yield. Both Merion and Newport varieties were mowed and windrowed six times over a 23-day period starting at a seed moisture of 50 percent for Merion and 45 percent for Newport. Again, seed color, shatter, and other criteria were found to be unreliable indicators of optimum maturity and cutting time. The optimum time to harvest both varieties of bluegrass was found to be at the first mowing and when seed moisture was highest. Since the optimum time was earlier in 1965 than the time that the crop had been harvested in any previous year, the study will be continued in 1966 and the test will start early enough to define the highest point on the pure-live-seed-yield curve.

Time-of-harvest studies were started on fineleaf fescue in 1965 to determine the optimum mowing time as indicated by pure-live-seed yield. Both creeping red and Chewings varieties were mowed and windrowed six times over a 35-day period starting at a seed moisture of 59 percent for creeping red and 57 percent for Chewings. The optimum time to harvest both varieties of fescue was found to be when seed moisture was 23 percent. This harvest date was 7 days after farmers mowed in the same field, and resulted in a 15 percent increase in pure live seed. Since this is the first year's study for fineleaf fescue, it will be continued at least one more year.

Seed moistures for all crops were again checked by both the exhaust oven moisture tester and the standard electric oven method. Readings with the exhaust meter were within $\pm$ 2 percent of the electric oven readings with a majority falling with $\pm$ 1 percent.

F. Oilseeds and Peanut Harvesting Equipment

1. Studies of pruning and training tung trees to facilitate mechanical harvesting showed that 3-year-old trees trained to a 5-1/2-foot height had significantly less total linear growth than untrained trees. However, there was not significant difference in yield of fruit. Neither was there a significant difference in yield when older trees pruned to a height of 5-1/2 feet were compared to unpruned trees of the same age.

2. Simplified design of a mechanical tung nut harvester resulted from blowing air through the nuts as they moved up the slotted rubber belt from the pick-up brush. This removes about 40 to 50 percent of the leaves and

eliminates the need for an inclined rotating drum which was originally designed for this purpose.

3. Peanut digger development. An experimental peanut digger equipped with an elliptical wheel dirt-removing assembly, was tested in Georgia and Virginia. Under Georgia conditions, the digger choked repeatedly with soil and vines, and excessive wrapping of vines occurred on the dirt-removing assembly. These tests showed that design modifications must be made if the digger can be used under these conditions. A commercial digger, used to dig Virginia-type peanuts in Georgia, left an average of 2,815 pounds of soil per acre mixed in the vines and 646 pounds of peanuts per acre in the soil (13 percent of the yield), indicating that improvements need to be made. Under Virginia conditions, the experimental digger performed more satisfactorily. Used when the soil moisture content averaged about 9 percent, the experimental digger left only 3,240 pounds of soil per acre mixed in the vines, compared to 23,510 pounds per acre left by the commercial diggers. With soil moisture content in the 13-15 percent range, the experimental digger left 8,210 pounds of soil per acre in the vines, whereas the average left by three commercial diggers was 25,180 pounds per acre.

4. Studies to determine the nature and extent of losses involved in harvesting peanuts showed that, under Georgia conditions, delaying harvest past normal maturity date greatly increases digging losses of Virginia-type peanuts. Spanish and Runner-type losses also increased as normal maturity was passed; however, the increase was not as large as with the Virginia-type. Next year, radioactive isotope tracers will be used to determine whether the peanuts were shed prior to digging or lost in the digging operations. This information should indicate whether a redesign of the digger would be beneficial.

5. A cleaner, consisting essentially of a hopper and two vibrating slotted screens, was used in studies on the separation of immatures and foreign material from peanuts. The cleaner removed from 84 to 96 percent of the immatures and from 55 to 62 percent of the foreign material; however, it also removed from 85 to 95 percent of the loose-shelled kernels. Larger percentages of all fractions were removed from semi-cured than from green-harvested peanuts. Additional work needs to be done to increase the efficiency in removing immatures and foreign material and reduce the loose-shelled kernel losses.

Preliminary investigations were made to evaluate shell damage caused by mechanical manipulation in combine harvesting of peanuts. These tests were conducted by harvesting freshly-dug peanuts and peanuts that had been in the windrow for 8 days. These tests showed that 28.6 percent of the green-harvested peanuts had shells damaged in combing. Of this total, 1.6 percent were damaged by the stemming saws and 2.6 percent were damaged by the air lift elevator. When peanuts were left in the windrow for 8 days, these two components were responsible for over half of the damage. With these peanuts, 12.1 percent had hulls damaged by the stemming saws, 6.7 percent

were damaged by the air lift elevator, and the total combing operation damaged 33.6 percent of the hulls. Since damaged hulls are considered to be conducive to the production of A. flavus, this work will be expanded.

G. Potato Harvesting Equipment

1. Mechanical injury of potatoes. Bruising continues to be one of the major problems in harvesting and handling of potatoes. The cantilever rubber flaps developed on this project for cushioning harvest conveyors are now commercially available. The impact instrument reported on last year for measuring potato susceptibility to bruising was used in extensive tests. The purpose of these tests was to determine methods for using the instrument so that it would be beneficial to growers. Bruising evaluations were made for five varieties of carefully dug potatoes. Also, bruising evaluations were made on potatoes obtained from commercial harvesters. An index number of the amount of mechanical damage was computed for both harvest injury and injury resulting from impact tests. This work will be summarized after harvest and a report prepared and published.

2. Multi-row harvesting of potatoes. Potato harvesters are expensive and anything that can be done to increase their efficiency or use is desirable. Multi-row harvesting methods are now being used by some growers. A comprehensive comparative cost analysis of two-row direct and four-row (multi-row) harvesting was made. This analysis indicates that multi-row harvesting can be advantageous with moderate to low yields when acreages are not in excess of 200. Owing to the substantial cost of a digger-windrower, the machinery ownership costs for harvesting machinery are increased by approximately 30 percent for four-row operation. There are also operating costs associated with the extra field operation. These additional costs must be more than offset by overall reduction of harvesting costs. This may be accomplished if the harvesting rate is sufficiently higher or a reduction in mechanical injury results in more marketable potatoes, or in a combination of these two factors. This analysis will be published early in F.Y. 1967 and should help growers determine when and when not to use multi-row harvesting.

3. Dust applicator for seed potatoes. Although dusting potato seed pieces has many advantages no commercial equipment for uniform application insuring complete coverage of the surface is available. Grower-made equipment does not contain dust to avoid air contamination in the work area. The experimental dust applicator described in last year's report was redesigned and modified. A rotating drum was used for the treatment chamber. Instead of the dust being introduced into a high velocity air stream, it was dropped directly onto the seed pieces as they entered the drum. Air from the system was drawn through a cloth filter. The unit was given limited trials on treating 30,000 pounds of cut seed potatoes. Results showed that dust was completely contained and that the seed pieces were completely covered. The unit will be used in treating a large volume of seed potatoes in 1966 to determine maintenance and operation problems. The design will then be released to manufacturers and the results published.

4. Engineering cost study of producing and harvesting potatoes. Potato growers invested over $10,000 for each potato harvester. Other equipment such as planters, cultivators, etc., are needed. An analysis of potato production and harvest costs for different acreage growers has been completed and a manuscript prepared for publication in F.Y. 1967. This report should be useful to potato growers in determining costs and needs and help them improve the efficiency of their potato operations.

H. Sugarcane Harvesting Equipment

1. Stalk measurements for harvesting recumbent-type sugarcane. Several types of bottom cutters for cutting the cane stalk from the stubble have been studied with the aid of highspeed photography. Two of the machines studied were used in Louisiana and encountered difficulties when cutting recumbent cane from the loose muck soils in Florida. The cane stalks were noticeably moved when contacted by the rotating blades. This indicates that the cutting action is not fast enough for the large, tough canes in Florida. Once the cane stalk was pulled between the two knives on the machines with double bottom cutters, it was sheared quickly. Cane trash was not severed by the bottom cutters unless it was sheared against the stalk. Bottom cutting is critical due to a very shallow root system. Many individual stalks have only about 2 inches of effective root lying below ground or below the desired cutting point. The design of a cutting and pickup device using two horizontal augers with pickup fingers is underway and a demonstration unit has been built. This component will be located directly above one of the present types of bottom knives and will also cut the cane into short lengths and discharge it onto a conveyor.

Power requirements for harvesting recumbent sugarcane. No direct measurements were made although observations were made on most of the commercial and experimental harvesters operating in the area. The ground knife sometimes consumes the entire power of the engine and stalls the harvester when entering rows. It seems that an excessive amount of power is expended in operating the bottom knife beneath the surface of the ground either through a lack of control of the cutting height or because of uneven field conditions. Excessively large diameter knives are required to cover the spread of the sugarcane stools and misalignment of the stools in the row. An improvement in this could result in a smaller diameter knife and a reduction in power requirements.

Cutter knife control. Several experimental ideas have been explored by research and commercial personnel in the Everglades sugarcane area where soil conditions make knife control difficult, yet necessary. Attempts at visual control by placing an operator where he can either see the knife or the cut stubble have not been satisfactory. The use of skids, floating knives, balancing springs, etc., have shown some promise. An automatic system with a feeler shoe operating a hydraulic valve which actuates the cylinder to lift the knife when it drops too low has been quite successful at one of the mills. A similar two-way control has been set up in the laboratory.

Effect of trash on harvesting in early season. Experiments were made in August and September when cutting unburned cane for planting. One commercial sugarcane harvester would operate at a slow rate of speed, but faster speeds caused green trash to wrap around the pickup augers and cause chokage. This harvester chopped the cane into short lengths with a knife that also cut the trash cleanly. About 45 percent of the seed pieces were split by the knife, but after adding a shear plate, this was reduced to 10 to 20 percent. Modifications were made to the throat of the machine to aid in picking up cane grown on flat culture.

A commercial sugarcane cutter was used to windrow seed cane which was picked up, chopped, and loaded by a conventional continuous loader. The large amounts of trash on the plants caused some chokages with this machine; however, more trouble was encountered by the continuous loader with trash accumulating behind the saws than with the harvester. In reasonably straight cane, this cutter could havest a one-fourth-mile row in 6 minutes. In the more recumbent canes, it could not be operated due to chokage around the bottom knife.

Cleaning cane for planting. The USDA Houma machine was operated for cutting seed cane to see what percentage of trash it would remove from Florida cane. In cane containing 32 percent trash, the machine topped and cleaned the cane down to 12.5 percent trash. Similar cane cut and topped by hand contained 13.9 percent trash. This cleaning principle is being tried by other producers for supplying cane to an experimental cane planter which will not work with trashy cane.

In operating this machine in Florida, the gathering chains had to be modified so that they could be lowered to pick up the recumbent stalks. Operation was best when these chains were allowed to run in the soil and no difficulties were encountered with this method. Cutting cane grown on flat culture caused a problem in disposing of the tops so that they would not be in the way when cutting the next row. Harvester efficiency was estimated to be between 80 and 85 percent.

Cleaning of cane on the conveyor. A cane orienting, cleaning and conveying device has been constructed in Florida for laboratory tests. It uses the notched-tooth cleaning principle in conjunction with a chain elevating conveyor. Combinations of notched-tooth cylinder speeds and chain speeds will be tried to determine the most effective orienting and cleaning speeds.

2. Mechanically removing tops and leaf trash from sugarcane. Experiments in Louisiana indicate that there is no significant difference in the density of the immature and the mature portions of the sugarcane stalk and that they cannot be separated by pneumatic means. There is, however, a significant difference in the density of the leaf material and the stalk so that these could be separated by any method utilizing the gravitational force of the materials. Pneumatic separation of the trash from mature cane is feasible only when the trash is detached from the stalk. Chopping stalks into short lengths is one method of detaching the trash. Tests to determine the

deterioration rate for chopped cane under various storage conditions were not conclusive. Studies of removing trash by burning indicate that green leaf material would be difficult to remove by flame. Burning of dry trash is best when sufficient quantities of trash are available to sustain combustion. This work is being done under contract by the Louisiana State University Agricultural Engineering Department in cooperation with the Audubon Sugar Factory.

3. Mechanization of sugarcane production in Brazil. Two experiments are underway at the University of Sao Paulo, Brazil, under research contract using PL 480 funds. This work is concerned with minimum tillage in sugarcane and with the development of a mechanical harvester.

Results from two production seasons show that when two varieties were planted on unplowed pasture and compared with conventional seedbed preparation: (1) Germination was not affected; (2) tillering was better in plowed plots; (3) there was no difference in soil moisture; (4) weed population was the same; and (5) there was no significant difference in production yield of cane.

Early research on the development of a harvester was devoted to the construction of a tractor-mounted-stripper which utilized wire ropes or flails for removing leaves from standing cane. It was felt that the topping and cleaning should be performed as one operation followed by a separate machine for the actual cutting and loading onto a wagon. Due to the short life of wire rope flails and resultant damage to the cane, additional research has led to the development of rayon-reinforced rubber flails which offer some solution to these problems. Utilizing this stripping system, a complete sugarcane harvester is now being designed that will cut the tops, clean the trash, cut off the cane and lay the stalks windrowed behind the unit to be picked up by ordinary loaders.

I. Tobacco Harvesting Equipment

1. Research was continued on the handling of stalk-cut air-cured tobacco on portable curing frames utilizing a front-mounted tractor loader. Approximately 40 man-hours per acre were required for (1) transporting empty and filled frames, (2) filling the frames at the field, (3) placing filled frames into a clear-span air-curing barn, (4) removing frames of cured "out-of-case" tobacco from the barn for placement into a conditiong enclosure, (5) conditioning with steam, and (6) removal of the "cased" tobacco from the frames for bulked storage preceding stripping the leaves from the stalk. Harvested tobacco, while field wilting on the portable frames, appears undamaged by rain provided the density of placement is not greater than one stalk per 48 square inches in plan section, and provided also the portable frame rails are sufficiently high to allow adequate ventilation. Objectives for further research are (1) continue study of labor and equipment performance, (2) continue determination of the effect of prolonged field wilting on tobacco, (3) develop an improved steel portable frame having

shop-fabricated components allowing simplified field assembly, (4) develop forced ventilation and supplementary heating procedures, and (5) develop a method of utilizing temporary plastic curing enclosures.

The objective of research on the handling of stalk-cut air-cured tobacco on vertically suspended strings is to design a harvest-housing system having more efficient use of men and equipment. A system is proposed utilizing a tobacco harvester having the function to fasten the base of cut tobacco to continuous twine. The "chain" of stalks is to be conveyed to a wagon drawn by the tractor-attached harvester. A portable drum-hoist at the top of a modified conventional air-cure barn will be used to pull the tobacco from the wagon. Control and power circuits for hydraulic or hydraulic and pneumatic harvester components have been designed. Curing tests have indicated satisfactory air-cure using the proposed procedure of handling. Further research includes completion of the design of the harvester and field testing of the harvest-housing system.

Development of a prototype harvester for stalk-cut tobacco. The objective of this work is to develop a machine to harvest stalk-cut tobacco in a manner which will utilize existing curing facilities and cause minimum physical damage to the crop. An offset-point spear was designed which pierces the stalk about 4 inches above the base and splits the stalk upward to a point about 10 inches above the base where the stick is inserted. This permits spearing without stalk positioning devices being located where they inflict injury to the leaves. The machine was partially constructed and the cut-off, conveying and spearing mechanisms were observed in the field. More than 98 percent of the stalks were properly impaled and spaced on sticks, while leaf injury was negligible.

Burley tobacco stalk strength properties. The objective of this investigation is to determine the plant's response to external forces which may be exerted by machines handling the crop. The flexure modulus of elasticity of stalk material which is a measure of stiffness, has been determined by testing both small uniform specimens excised from the stalk and sections of intact stalk. A procedure was developed to take into consideration the taper of the intact stalk sections using a finite number of discrete intervals. This procedure yielded a value of 399,000 p.s.i. as compared with 406,000 p.s.i. for the material determined from the small uniform specimens. Future plans are to investigate other varieties and also cured stalks to obtain data useful in the design of machinery to handle the cured plant.

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AREA 5: CROP PREPARATION AND FARM PROCESSING (EXCEPT COTTON)

Problem. The programs of research in this area are concerned with the development of better methods, techniques, and equipment for use on farms for the initial preparation for market or the processing of farm products to increase efficiency in the use of labor and equipment, and to preserve quality and prevent spoilage and damage from mechanical handling. While considerable information has already been obtained for the development of processes such as drying and separation, basic and more precise information must be developed for these and other processes in order to achieve further progress. The underlying principles that pertain to the cleaning and drying of different crops, curing of tobacco and peanuts, and sorting need to be determined. The methods for processing farm crops are largely dependent on production practices and dictated by future handling or storage requirements. Consequently, this requires interdisciplinary collaboration in the creating of a completely mechanized program of crop production.

USDA AND COOPERATIVE PROGRAM

The Department's effort in this area constitutes a long-term program involving agricultural engineers and statisticians engaged in both basic and applied research on the engineering phases of crop preparation and farm processing. Seed cleaning research is currently being conducted at Corvallis, Oregon, in cooperation with the Experiment Station and private industry. Research on tobacco curing and sorting is cooperative with the Experiment Station at Lexington, Kentucky. Research on the drying of grain is cooperative with the Experiment Station at Ames, Iowa, equipment manufacturers, and farmers. Forage processing is under study at Beltsville, Maryland, and at Tifton, Georgia, in cooperation with the Coastal Plain Experiment Station. Manufacturers cooperate through loan of equipment. Research on the processing of tung nuts is conducted at Bogalusa, Louisiana, in cooperation with the Mississippi Experiment Station and industry. Farm curing and drying of peanuts is cooperative with the Virginia and Georgia Experiment Stations.

The Federal engineering effort devoted to research in this area totals 10.3 scientific man-years. Of this number, 2.5 are devoted to seed cleaning, 1.0 to curing tobacco, 4.9 to drying of grain, 0.8 to forage processing, 0.4 to tung nut processing, 0.2 to peanut curing, and 0.5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Many freshly-harvested agricultural crops must be subjected to early treatment in order that they may retain as much as possible of their original qualities. The state agricultural experiment stations are involved in both basic and applied research studies which have as their broad objectives

the development of improved methods, equipment and techniques for preparation and processing of farm crops to preserve quality and prevent spoiling while in storage.

The scope of the current program may be best illustrated by describing it in broad areas of study.

Drying or curing investigations are in progress on forage crops, cereal crops including rice, feed grains including grain sorghums and soybeans, nuts, tobacco, peanuts and coffee. Farm processing studies are under way for forage wafering and hay storage; precooling of freshly-harvested crops such as citrus, sweet corn and vegetables; pre- and poststorage treatment of potatoes; dehydration and mechanical dewatering of crops; seed and grain cleaning and separation; and trimming, peeling, and juicing operations for crop marketing.

Closely associated with these studies are development and adaptation studies of flow systems, equipment and packages to move products without damage into and out of storages and to the market place.

Much of this research is cooperative with the Department.

A total of 29 scientific man-years effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Seed Cleaning

1. Seed cleaning research applied to specific problem mixtures. Seed cleaning research was continued in the attempt to improve upon existing techniques for processing given seed mixtures--either by performing a more precise separation with conventional equipment or by developing and using new equipment to better exploit seed differences. The recurring problem of separating various contaminants from bentgrass was again considered. Dirt clods were removed effectively with a gravity table and a special indent cylinder. Mouse-ear and other short weeds also responded well to the special indent. A different contaminant--spike bentgrass--could not be removed satisfactorily even by extensive trials with the pneumatic, velvet roll, vibrator, and gravity (sandpaper deck) separators. Seed measuring and screening trials were carried out to determine the best screen and indent sizes for separation of certain seed mixtures. Separating results predicted from seed measurements were then correlated with actual screening tests. Compilations of seed measurement data were processed to obtain arithmetic means and standard deviations for length, width, and thickness dimensions. These values were established for Kentucky bluegrass, Colonial bentgrass, alfalfa, and cotton. In equipment development, the single-deck vibrator separator continued to demonstrate its versatility by removing various weed seeds from white clover, carrot, alfalfa, orchardgrass, and Rhodes grass. Brief trials with the resilience separator showed that quantity and purity of final fractions

from a seed lot could be varied by moving the bounce plates horizontally or vertically. In separator testing, the magnetic process was investigated to learn how separation efficiency is influenced by amount of moistening liquid, types of metal power, and additives like soluble oil and wetting agents. These variables were evaluated in different test combinations by determining how effectively dodder and buckhorn plantain were removed from red clover. In general, the amount of liquid was found important but liquid additives were relatively unimportant. About one-third pound of water per bushel of seed was optimum. Metal type also was important, with the finer metals doing the best job of removing weed seeds. In testing the color separator, various contaminants were removed from beans, rice, mustard, onion, safflower, barley, and soybeans. Other brief trials were conducted to learn how a given product responded to different arbitrary combinations of colored filters and background colors. In pneumatic separator tests, the selectivities of five machines (with various modifications) were compared by separating standard test lots at two air velocity ranges. By analyzing the relationship between material lifted and lifting-air velocities, numerical rankings were established for individual machines or modifications within batch or continuous flow groups. In addition, batch separators as a group were found more selective than continuous units. Round and square column shapes showed about equal selectivity in batch tests, but were far exceeded by a zigzag column. Given separators changed ranking spots when tested at both low and high velocity. Finally, the selectivity of a separator tended to decrease as terminal velocity of the product handled increased.

2. Development and testing of the centrifugal screen separator was continued during 1965. A number of mechanical changes were made that provided considerable improvement in the smoothness of operation and in mechanical dependability. Additional study was devoted to possible designs for a new model with mechanical changes which would enable the new machine to be used as a component of the separator section of a combine. This development could revolutionize the separation of granular material that would increase both machine capacity and efficiency, resulting in a higher quality product at a reduced cost.

B. Tobacco Curing

1. Ventilating fans for curing burley tobacco in conventional barns. The objective of this research was to improve curing conditions in a conventional barn, using conventional handling practices. Supplemental heat and forced ventilation were used. In normal burley curing, the tobacco may be damaged due to poor drying conditions in the barn which occur during periods of high humidity. This is especially true in certain multi-purpose structures where provisions for ventilation are inadequate. Ventilating fans offer convenience of both air movement and lower relative humidity by affording a method of adding supplemental heat. Fans were installed in a curing shed near Russellville, Kentucky. This work was done by research agricultural engineers in cooperation with county agents and extension specialists. The outside of the multi-purpose structure (curing shed) was

covered with plastic up to the top sill to eliminate side drafts which would interfere with the fan ventilation.

Data were collected on the effects of ventilating fans in curing burley at two farm locations and at two barns on the University of Kentucky Experiment Station. Results indicated that tobacco could be satisfactorily cured at one-half the normal stick spacing, provided both ventilation and supplemental heat were used during high humidity conditions, and the tobacco did not overlap between tiers. Heat should be used to create not more than a 10° to 12° F. temperature rise in the barn.

Curing primed burley tobacco. The objective of this research was to determine the feasibility of curing primed burley. Work was directed toward developing an accelerated curing schedule. One alternative to cutting, housing, and curing whole plants is to take the leaves from the stalk as they ripen. This would have the advantage that mechanical defoliators already developed in the Southeast could be used to harvest burley leaves. However, this would depend on whether burley tobacco cured off the stalk would be acceptable in the trade. Burley is traditionally an air-cured product and takes 6 to 8 weeks to cure on the stalk. A 2-week curing cycle would have the advantage of allowing more economical use of curing facilities. In addition, the quality of the end product is made more predictable through better environmental control during the cure. This would mean the farmer could cure his tobacco independent of weather.

The experiment was designed to determine the effect of leaf moisture content at various stages of the cure on the physical and chemical characteristics of the cured leaf. Leaves were taken progressively from bottom to top of the stalk at 5 biweekly intervals. Tests were conducted in the laboratory under close control of the curing environment. Leaf samples for chemical analyses were taken from the primed tobacco at 3-day intervals during each biweekly curing phase. Curing treatments consisted of (1) wilting to 500 percent m.c. (moisture content, dry basis) and drying at 90° F., 80 percent r.h. (relative humidity); (2) wilting to 400 percent m.c. and drying at 60 percent r.h.; (3) wilting to 200 percent m.c. and drying at 80 percent r.h.; (4) wilting to 200 percent m.c. and drying at 60 percent r.h., and (5) stalk-cured control cured at 90° and 70 percent r.h.

Based on visual observations of the cured tobacco, a humidity of 80 percent at 90° F. and a relatively high air flow rate of 90 ft./min. consistently produced an acceptable cured product in a 2-week period. This seemed to be true regardless of whether the tobacco was wilted initially to a normal 400 percent m.c. or to a subnormal 200 percent m.c. Primed leaves which were subjected to 60 percent r.h. during most of the curing period dried too fast as indicated by yellow color in the leaf web at the end of the curing period. Further comparisons of the two curing methods, priming and stalk curing, were made on the basis of standard grades. These comparisons indicated no significant difference between the two curing methods. Comparisons of priming treatments based on chemical analyses showed that protein

nitrogen decreased about 40 percent during the first 3 days of the cure, but showed little change thereafter. Since protein nitrogen decreased by as much as 50 percent during normal curing, this was taken as an indication that the major part of the curing phase took place within 3 days under the experimental conditions tested. No meaningful comparisons of curing rate could be made with stalk curing since the stalk-cured tobacco was sampled only at the beginning and the end of the tests. These results will be of benefit to the public by pointing up methods which will reduce production costs through more economic use of curing facilities. This research will be continued by measuring the progress of the cure by leaf chemical analysis and smoke panel evaluations.

Mass and energy balance of burley tobacco during the cure. The major objective of this investigation is to obtain data for the design of controlled or modified environment curing structures for burley tobacco. This design will require knowledge of the basic properties of tobacco under various curing conditions. The lack of information reported in the literature and the potentials of applying knowledge of respiration heat and moisture removal to the curing system prompted this study. The major ventilation loads for an air-cure system are the heat and moisture produced by the respiration process and the free moisture evaporated from the tobacco. An apparatus suitable for measuring the effect of temperature, humidity, density, and air flow rate on the various mass and energy exchanges between the curing tobacco plant and its environment has been constructed. This respiration chamber is presently being calibrated. Plans are to conduct a series of 16 tests using the intact tobacco plant at 60, 70, 75, and 80 percent relative humidity and 70°, 80°, 90°, and 100° F. Results will help to determine conditions for future studies. An air flow rate of 8 f.p.m. will be used. Test length will be determined from the preliminary studies. These results can then be used as a basis for determining how much heat and moisture would have to be removed from a controlled or modified environment curing structure.

C. Grain Drying

1. At Ames, Iowa, studies are underway for isolating the factors that enter into rational design of drying equipment and develop quantitative descriptions of their relation to economic design. Measurements of the rate of moisture loss from thin layers of kernels are made to determine the separate effects of air temperature, air humidity, air velocity, initial grain moisture, initial grain temperature, and other grain properties on moisture movement. In exposed kernel drying, about 50 grams of kernels are arranged in a single layer for air to pass through. The weight is observed periodically to observe the rate of loss of moisture. With soybeans, a consistent pattern is observed at all conditions of initial moisture, air velocity, air temperature and humidity, initial kernel moisture, and initial kernel temperature. The consistency is such that numerical coefficients can be assigned to describe the effect of each. The coefficient for velocity is poorly defined; partly because of the difficulty of controlling and

measuring velocity in the vicinity of the kernels. High velocity has the effect of speeding the drying during the early stages but has no observable effect on the drying rate later in the drying period. The effect of initial grain temperature was also poorly defined. If the grain is cold when the test is started, drying is slowed for the first few minutes. In some cases the moisture content may actually increase before any moisture is lost. The net effect of low initial temperature is to delay the drying so that it takes longer to reach any given level of moisture. In these tests the delay ranged from 2 to about 10 minutes. The numerical coefficients describing the effects of the other factors repeat themselves pretty well from test to test.

Earlier tests on counterflow drying of corn have been analyzed more completely to yield design data for practical counterflow drying equipment. These results show how the necessary drying time is related to depth of grain bed and how much increase in drying capacity can be accomplished by the sacrifice of given percentages of fuel use efficiency.

2. Studies of the drying zone in mechanical grain driers were continued through use of laboratory model drying bins. The drying zone refers to that part of the grain in a drying bin in which drying is actually taking place at any time. The zone moves through the grain but, in general at any time during drying, part of the grain is drying, part is already dry, and part is still at its initial moisture. The temperature and moisture gradients in the drying zone determine the efficiency and the required drying time in any drier. Accurate definition of the drying zone in terms of grain moisture, air temperature and humidity, rate of airflow, etc. would permit rational design of drying equipment. While much progress has been made in relating these factors to the drying zone, drier design still remains an art without the support of adequate design data.

Very good data were obtained from the measurement of temperature with thermocouples spaced through the column of grain in model bin driers. Contrary to common expectation, it was found that the profile of temperature in the drying zone did not reach a fixed pattern and then proceed unchanged as the drying zone moved on through the rest of the grain. No static or steady state condition of temperature change was detected. In tests in which the drying air conditions were maintained constant, calculations of the amount of water removed from the grain based on temperature and airflow measurements agreed within 1 to 5 percent with measurements of water removed based on changes in weight of the grain. From this it can be concluded that the apparatus and techniques have been perfected to allow the collection of reliable data. The problem remains to generalize the data with a mathematical model.

3. Effects of mechanical damage to field-shelled corn. The effects of several different damage treatments to corn kernels on the deterioration rate of 28 percent moisture corn were studied. The general observation would be that damage to the embryo of the kernel is more serious than

damage to the endosperm. The results are expressed with relation to the deterioration rate of hand-shelled corn with little or no damage. An arbitrary figure of 1.0 was chosen to represent the deterioration rate of undamaged hand-shelled corn. Hand-shelled kernels sliced with a razor blade on the endosperm had a relative deterioration rate of about 1.2. Kernels with the crown cut away had a relative deterioration rate of 1.9. In contrast, kernels which were treated with impacting the embryo without rupturing the skin had a deterioration rate of 2.0. Those treated with puncturing the skin over the embryo with a pin had a relative rate of 2.2. Kernels in which the skin over the embryo was sliced with a razor blade had a relative rate of 2.4 and kernels in which the tip was cut off had a relative deterioration rate of 2.85. It was observed that the relative deterioration rate of whole sound kernels selected from a sample of corn that had been shelled in the field had the same rate of deterioration (2.0) as hand-shelled corn in which the embryo had been bruised with an impact tool. One major equipment manufacturer has started an active program of checking mechanical damage with their harvesting machines.

4. The time limitation on storing grain under any given condition is dictacted by grain deterioration which is caused primarily by the growth of molds and bacteria. Of secondary importance may be the respiration or growth of the seed itself. The factors which influence the rate of growth of the microflora are grain moisture, temperature, and the amount of physical damage of the grain. It is the purpose of this study to evaluate the influence of these factors on the rate of growth of the microflora and subsequently the rate of deterioration.

Improved techniques and apparatus allowed the measurement of carbon dioxide production from shelled corn with as little as 13 percent moisture. Carbon dioxide production was measured from samples of hand-shelled corn, field-shelled corn, and hand-shelled corn that had been treated with different types of damage. Most of the studies were made with corn at about 28 to 30 percent moisture content. Some samples of hand-shelled and field-shelled corn were studied at several moistures between 28 and 13 percent. All studies were carried out at 65° F. The relative rate of carbon dioxide production between field-shelled corn and hand-shelled corn was about 3 to 1 for all moistures. The differences found in the rate of carbon dioxide production as correlated with type of damage to the kernel indicate that damage to the embryo results in faster deterioration than damage to the endosperm. Traces of aflatoxin were found in some samples of corn from the samples on which carbon dioxide production was measured, but so far there is no way to tell whether temperature or moisture levels influence the aflatoxin production.

D. Forage Processing

1. Artificial drying energy requirement studies showed that the drying efficiency of a forage dehydrator drops rapidly as the moisture content of the incoming material is reduced. Equations were derived to show both the

energy required to evaporate 1 pound of water from hay with various initial moisture contents and the energy required to produce 1 ton of dry matter from hay with initial moisture content ranging from 10 to 85 percent.

The effect of unit processes on the economically important constituents in Coastal bermudagrass and millet showed the following: As the age of Coastal bermudagrass increases from 3 to 5 weeks, the percent of protein and the carotene decrease. With this decrease is also a decrease in moisture content and an accompanying decrease in processing energy requirements. As a result of these factors, the processing energy cost per pound of protein and per million units of carotene is relatively constant. The maximum production per acre of these two constituents was obtained from cutting every 4 weeks. Millet contains considerably more protein and carotene than Coastal bermudagrass. It also has a much higher moisture content and higher processing energy requirement, causing the processing unit cost for these ingredients to be approximately 50 percent higher than for Coastal bermudagrass.

A study of the effect of the addition of fines to clean pellets showed that, regardless of the initial bulk density of either the pellets or the fines, the bulk density was increased by the addition of as much as 15 percent of fines by weight.

Processing treatments were applied to Coastal bermudagrass to determine their effect on digestibility. Digestibility was evaluated by the nylon bag in fistulated steer method. Dry matter disappearance, compared to the control, ranged from negative values for some treatments to a 13 percent increase in others. The greatest increase was obtained from the poorest quality forage.

E. Tung Nut Processing

1. Studies of hulling of tung nuts on the farm show that commercially available walnut hullers can be used for this purpose. One such machine was tested and found to have a capacity of 3 tons per hour. Losses of oil-bearing material ranged from 6 percent in fruit with 30 to 40 percent moisture to 9 percent when the fruit contained 20 to 30 percent moisture. By hulling on the farm, transportation costs will be lower and the guaranteed oil recovery percentage will be higher.

2. Studies on farm conditioning and storage of tung nuts were not conducted in 1965, because the crop was extremely light and dry and harvesting was completed by December 1.

F. Peanut Curing

1. Equipment was constructed to determine the feasibility of rapid drying of peanuts to reduce the potential for aflatoxin development. This unit allows precise control of airflow rate, temperature and humidity. Preliminary tests indicate that, by alternately passing hot and cool air

through the peanuts, the drying rate may be increased without reducing quality. More extensive tests are planned.

2. Combine-run and recleaned peanuts were compared for airflow resistance and drying rate, using both green-harvested peanuts and peanuts which had been partially cured in the windrow. In the test boxes which were 1-foot cubes, there was not any statistical difference between combine-run and recleaned peanuts in either airflow resistance or drying rate. Since some loss of loose-shelled kernels occurs, recleaning combine-run peanuts does not appear profitable. Since the foreign material may tend to accumulate in large bins, areas of poor drying may occur, leading to the possibility of A. flavus production.

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AREA 6: COTTON GINNING

Problem. This area is specifically concerned with the separation of the cotton lint from the cottonseed and those associated processes that pertain to cleaning, drying, handling of lint, seed, and trash, packaging, and sampling, to preserve the inherent qualities of the end products. This is the final operation in the process of cotton production since, subsequent to ginning, title of the lint and seed passes from the producer to a buyer and the products enter the market channels.

Although developments growing out of the USDA Ginning Research Program have been revolutionary, there are many problems yet to be solved, some of which are growing acute. The need is increasing for further automation of the ginning processes to effect better quality control and reduced labor costs.

In their quest for lower unit costs, mills are continually increasing machine and processing speeds. At the same time the trend continues to demand cleaner cotton. Thus with the farmer gathering more foreign matter with the cotton because of mechanical harvesting, the cotton trade demanding cleaner fiber for a given grade, and the manufacturer demanding more performance, the gin's role becomes most complex. More efficient cleaning equipment which will minimize fiber degradation at reduced labor and power costs is among the more urgent needs.

USDA AND COOPERATIVE PROGRAM

The USDA has a continuing long-term program involving agricultural engineers, physicists, and cotton technologists engaged in basic and applied research on the engineering phases of cotton ginning. Gin performance and cotton quality and waste collection and disposal research is being conducted at Clemson, South Carolina; Mesilla Park, New Mexico; and Stoneville, Mississippi. Research on seed cotton cleaning and cottonseed is underway at Clemson, South Carolina, and Stoneville, Mississippi. Seed cotton handling, seed cotton conditioning, and conveying research is underway at Mesilla Park, New Mexico, and Stoneville, Mississippi, while work on gin stands is currently carried on at Clemson, South Carolina, and Mesilla Park, New Mexico. Lint cleaning and packaging research is carried on at Stoneville, Mississippi. Research is cooperative with state experiment stations, Economic Research Service, industry, and individuals, as well as other Divisions in the Agricultural Research Service.

The Federal engineering effort devoted to research in this area totals 14.5 scientific man-years. Of this number 0.6 is devoted to seed cotton handling and storage, 1.1 to seed cotton conditioning, 2.0 to seed cotton cleaning, 0.6 to conveying, 1.5 to gin stands, 4.7 to gin performance and cotton quality, 0.5 to lint cleaning, 0.5 to packaging, 0.6 to cottonseed, and 1.9 waste collection and disposal, and 0.5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Research in this area is conducted in only two State Agricultural Experiment Stations; namely, Oklahoma and South Carolina. The Department has been specifically concerned in this area for several years and has carried on the major program of research on the engineering phases of premarket cotton processing and handling.

The Oklahoma research involves the adaptation and testing of cotton ginning equipment, techniques and related operations for reducing the cost and delay in handling and conveying seed cotton on the gin yard and in the gin. In addition, evaluations are being made of the quality reductions associated with green and immature bolls in harvested cotton as well as determination of the effects that various combinations of cleaning, drying, and ginning machines have on returns to the producer.

The South Carolina studies are concerned with the development of new principles and techniques for ginning cottons. Characteristics and properties of seed cotton, lint, and seed related to the basic ginning processes are being investigated as well as the effects that various physical actions have on fiber and seed.

A total of 2.5 scientific man-years are devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Seed Cotton Handling and Storage

1. At Stoneville a seed cotton unloading system which was fabricated last fiscal year was installed in the full-size laboratory gin for testing. The system consists of a dump trailer, receiving hopper and automatic metering device for feeding the cotton at an even flow rate to the ginning equipment. Preliminary investigations show that the system should have promise in reducing labor and horsepower requirements.

B. Seed Cotton Conditioning

Work at Stoneville:

A drying parameters study using a moving bed drier showed that drying seed cotton 30 seconds at 350° F. did not harm the germinating properties of seed at 9 percent moisture, but did adversely affect germination of 12 percent moisture seed. Drying at 400° F. reduced germination of the 9 percent moisture seed by 10 percent and 450° F. drying reduced germination over 20 percent. These data support the recommendation that 350° F. should be the maximum temperature in gin drying systems.

Investigation into electrode design for automatic fiber moisture control systems showed that a multi-band section in a conventional bulk cotton feed roller would make an excellent electrode system for raw cotton moisture detection.

Experiments with greenhouse cotton grown with and without Thimet, a phorate based insecticide, showed that this chemical does not constitute an error source to automatic drying control of gin drying systems. Comparison of specimens tested raw and after distilled water washing showed the electrical resistance of the washed specimens to be more than twice as great as that of the raw specimens. This suggests that weathering may affect raw fiber electrical resistance.

Comparison of commercially ginned cotton and similar cotton ginned at the laboratory after 60 seconds vapor addition failed to show consistent gains in fiber and spinning quality. The moisture restoration method was deemed inadequate.

Investigations into the effect of bulk density of cotton on its specific electrical resistance showed that within the limits of the experiment ($d = 0.2$ to 1 gm/cm^3) the logarithm of the specific resistance is linear with density, and that for practical purposes changes in fiber moisture content produce greater response in the resistance measuring system than do changes in bulk density.

Comparison of data obtained with 400 volts DC and 400 volts at 60 H_z showed no difference in electrical resistance attributable to type of voltage. Statistical analysis of these data showed coefficients of variation of 15-20 percent to be expected from 10-replicate tests.

Work at Mesilla Park:

Tests were made to determine the variation in the electrical resistance of lint cotton with changes in temperature while the moisture content is held constant. The studies showed a rate of change in resistance of 1.7×10^6 ohms per degree F. with the lint in moisture equilibrium with air of 75 percent relative humidity. The temperature range was from 70° to 85° F. This falls within the lower limit determined for this temperature and moisture range in preliminary tests in early 1965.

A study was made to determine the capabilities of various moisture conditioning equipment arrangements in a mono-flow ginning system, their effects on lint foreign matter content and fiber length preservation, and whether the system would function as designed. The results were very satisfactory with some need for modification indicated. The tests showed that for both seed cotton cleaning and lint cleaning, increasing the cotton moisture content decreased the cleaning machinery's cleaning efficiency as indicated by measurements of foreign matter in samples taken at the feeder and before lint cleaning.

The ginned lint 2.5 percent span length before lint cleaning was directly proportional to cotton moisture content at time of ginning. Reducing moisture content at the time of ginning resulted in reduced fiber length as expected. The feeder seed cotton moisture contents had a +.70 correlation with the fiber length.

Field studies made in connection with the design of the monoflow system show that cotton in the Southwest is ginned under extremely dry conditions. Observations over a 16-week period showed atmospheric conditions to range from 100° F. with 5 percent r.h. on 10-8-65, to 38° F. on 12-8-65, and from 2 percent r.h. on 9-29-65 to 80 percent r.h. on 12-10-65. The weighted average gin temperature was 74° F. The weighted average relative humidity was 24 percent. Seventy-six percent of the time the gin relative humidity was below 5 percent fiber moisture equilibrium conditions.

C. Seed Cotton Cleaning

1. Field survey data collected at four high capacity gins near Stoneville showed that the seasonal average grade was 92.8 and ranged from a low of 90.4 to a high of 94.5 The wagon sample moisture content was comparable for all four gins, averaging 13.0 percent and the wagon sample foreign matter content averaged 7.1 percent. Seed cotton cleaning efficiencies for all four gins combined averaged 59.2 percent and ranged from a low of 51.3 percent up to a high of 65.3 percent. Based on past studies, seed cotton cleaning efficiency on such machine picked seed cotton should have been about 70 percent. The lint foreign matter content for all four gins averaged 2.69 percent, and the highest seasonal average was 2.98 percent. The seasonal lint moisture content for all four gins combined averaged 4.5 percent, with the lowest seasonal average at 3.2 percent and the highest at 5.3 percent. The operators at all four gins tended to over-dry their cotton.

Seed cotton rate of feed tests at Stoneville showed that foreign matter removal was directly proportional to rate of feed. The use of double lint cleaning tended to level out the differences, however. There were no important differences in fiber length or yarn strength associated with the different rates of feed.

Tests at Stoneville on the limb and stalk removal machine showed that one cleaning cylinder of the machine was about as effective as two. Furthermore, it would be advantageous to include one cylinder employing this cleaning principle as the first cylinder in commercial stick and green leaf machines. This recommendation has been made to the industry.

In areas where crop rotation between castorbeans and cotton is practiced, some trouble from volunteer castor plants in cotton fields has been encountered. It was feared that seed harvested with the cotton may cause contamination of cottonseed products such as cattle feed. About a bushel of 1965 crop castorbeans were shipped to the U.S. Cotton Ginning Research Laboratory at Stoneville from the Plainview, Texas, area for experimental purposes.

Four-pound machine-picked cotton lots were contaminated with castorbeans to simulate field conditions in castorbean production areas. The treated lots were then processed through the machinery in the micro-gin plant were effectiveness of castorbean removal by the individual machines and combinations of machinery was determined. It was found that when seed cotton containing castorbeans at the rate of two whole beans plus one bean cut into three pieces per pound of seed cotton was processed through normal gin machinery combinations, all castorbeans were removed. A few small pieces of the capsule came through with the cleaned seed cotton in four of the twelve test lots but all of the whole beans and pieces of beans were removed.

2. Hand-picked cotton was used in the evaluation of a moving grid-type lock separator at Clemson. Little or no improvement in quality was noted from the use of this machine when the tight lock content of the cotton was very low. However, grade and staple length are improved in proportion to the amount of this inferior material removed from the cotton.

D. Conveying

1. Tests were run at Mesilla Park to obtain data on the air flow characteristics of an air-jet type conveyor. This information is required in order to formulate general design procedures for sizing conveyors and fans for various cotton ginning applications.

From an investigation of the air-jet conveyor's orifice slot openings the relationship between air discharge per orifice slot and plenum static pressure was determined. A general formula was developed to express the air discharge per orifice slot in terms of the slot size and plenum static pressure. This information can be used directly in the design of air-jet conveyor systems.

Various lengths of air-jet conveyor were tested to determine the energy losses associated with the movement of air inside the conveyor's plenum chamber. Two sizes of conveyors were used in this series of tests. It was found that energy losses inside the plenum chamber could be divided into frictional losses and losses due to turbulence. Both types of losses were found to be directly proportional to the velocity pressure of the air entering the conveyor plenum chamber. Further analysis of these data provide specific relationships for predicting energy losses for various lengths of the two sizes of conveyors tested. In addition, it was found that the frictional losses inside the plenum chamber could be determined from conventional friction loss charts for closed duct systems by applying an appropriate correction factor. When covers were placed on the open conveyor trough, energy losses and power requirements were increased. The amount of increase depended upon the length of the conveyor and distance that the covers were placed above the orifice plate.

The ability of the air-jet conveyor to transport cottonseed was also investigated and the maximum cottonseed conveying capacity of the air-jet

conveyor for various air flow rates was determined. Three conveyor positions were tested: Horizontal, inclined 30 degrees and inclined 45 degrees. Both Pima and upland cottonseed were used in these tests. Test results also indicated that the power requirements would be comparable to a conventional small pipe cottonseed handling system.

E. Ginstands

1. Tests made at Clemson with and without 40 percent of a gin roll box surface coated with Teflon showed that the average tangential velocity of the seed roll without Teflon was 196 feet per minute while that with Teflon was 205 feet per minute. This is an increase of 9 feet per minute. The average density of the seed roll was less with Teflon than without it. Thus by using Teflon a higher rate of feed may be maintained without increasing seed roll density, hence the capacity of the gin increased. By making the assumption that the seed roll must turn the same number of revolutions to gin a bale of cotton, the increase in capacity would be 4.5 percent. If this increase varied linearly as the amount of the Teflon coating increased, then a projected increase in capacity would be 11 percent for 100 percent roll box coverage. Further investigations will be made.

2. At Mesilla Park, roller ginning rate potential studies started in 1964 showed that maximum ginning rates obtained during that year were 25 and 19 pounds of lint per inch of roller per hour for Pima and Acala 1517, respectively. Further changes in the feeder and lint duct system were made in 1965 and 12 ginning treatments were applied to both Pima and Acala 1517 cottons. The maximum treatment (roller speed 200 r.p.m. and roller-to-fixed-knife-pressure 155 p.s.i. gage) gave ginning rates of 40 and 34 pounds of lint per inch per hour for Pima and Acala, respectively. These correspond to a little over and a little under three bales an hour for the respective varieties using a 40-inch wide stand. If the seed cotton feed and gin adjustments are optimum, the ginning rate depends only on the roller surface speed and roller-knife pressure. The effects of roller surface speed and roller-knife pressure on ginning rate were found to be independent of each other in the ranges tested. The high ginning rates did not cause any noticeable changes in fiber quality but no spinning or extensive fiber tests were made. The maximum ginning rates have probably not yet been achieved as the gin drive unit was operated at or beyond its power rating and the feeder was probably at its upper limit on the higher rate treatments.

3. Studies of the angular position of the stationary knife to the roller was made in a high-capacity rotary knife type gin at Mesilla Park. An analysis of ginning, lint, and limited fiber data showed that for Acala cotton the best ginning and highest ginning rates were obtained with the stationary knife set at the normal angle. There were no noticeable differences between the treatments for Pima indicating that this particular adjustment is not as critical as previously thought when ginning Pima.

F. Gin Performance and Cotton Quality

Quality Evaluation:

1. A short method for seed cotton moisture determination developed at Stoneville shows that an operator can calculate moisture content after 2 hours of oven drying as precisely as is found by testing two specimens from the same sample container using the regular 5-hour drying oven procedure. Based on these tests, use of the 2-hour oven drying method is recommended in studies where the primary objective is not moisture evaluation. Also an equation was developed for calculating lint moisture content after 10 and 15 minutes of oven drying. For a lint moisture content less than 10 percent using this equation, a precision of $\pm$ 0.3 percent can be expected on two-thirds of the samples tested.

Studies at Mesilla Park showed that seed coat fragments did not appear to vary between strains of upland, or strains of Pima for harvesting, cleaning, or conditioning treatments. They are caused by mechanical treatments and generally may be reduced by lint cleaning. They tend to reduce spinning performance and yarn quality. A measure of seed coat fragments is used in evaluating gin equipment.

Work on the refinement of a seed coat fragment test at Stoneville has emphasized the need for counting the small fragments which account for less than 20 percent of the total by weight because they are the most difficult to remove from lint with any cleaning treatment.

At Clemson, tests were made by adding known quantities of tight locks to the test cottons. The range studied varied from 10 to 100 percent tight locks in 10 percent increments. Data from two harvest seasons showed quality values tended downward consistently as the quantity of tight locks in the seed cotton increased.

2. The cause of neps in ginning was studied at Mesilla Park. Pertinent findings with respect to these tests are: (1) Gin saw speed over a range of 200 to 800 r.p.m. does not affect fiber nep generation; (2) saw gin seed roll density does affect nepping; neps increase with increased roll density; (3) fiber moisture does not affect or is a very minor factor in nep formation in a saw gin stand; (4) there is a highly significant difference in nep formation between saw and roller ginning with roller ginning yielding the least neps; (5) mechanical treatment of seed cotton prior to ginning affects nep formation in both saw and roller ginned lint, neps increasing with more severe treatment; and (6) the results of tests on the effect that modification of fiber surface friction has on nepping were inconclusive.

3. At Stoneville a technique of combing at 90° to clamps holding the specimen has proven promising in a method for determining the short fiber content of a sample. The results correlated significantly with data from

fiber arrays but there was considerable variation between individual tests. The time required for the test by one operator was about 12 minutes which is 54 minutes less per sample than is required for the array.

Tests of a fiber sorter developed at Mesilla Park, after modification, showed that fiber fineness affected short fiber determinations with the instrument. When a correction was made for fiber fineness, the correlation with the Suter-Webb Sorter was raised from 0.80 to 0.85 with a standard error of $\pm$ 2.2.

4. At Stoneville two experiments were conducted for investigating the relationship of drying air temperature to irreversible fiber damage as determined by fiber breakage. A bulk cotton drying study showed a trend toward increased fiber damage as temperature increased, but a tightly controlled 10,000 fiber test where 1,000 fibers were tested for irreversible fiber damage after drying for 30 seconds at each of 10 temperatures from 25° to 250° C., showed (1) no significant effects among temperatures up to 100° C., (2) a tendency toward increased fiber breakage as drying air increased from 100° to 175° C., and (3) a rapid and substantial increase in fiber breakage at temperatures of 200° C. and over. It is, therefore, recommended that USDA go on record as disapproving the use of temperatures above 175° C. (347° F.) in cotton ginnery drying systems. This temperature recommendations is in addition to, and does not modify, the recommended ginning fiber moisture content of 6-1/2 to 8 percent.

Tests to determine the effect of temperature on ginning rate at Mesilla Park with both Pima and upland cotton showed that there were no differences between treatments for upland but Pima ginned faster when hot. Investigations are underway in an effort to determine why.

5. A study of the effect of gin cleaning, processing performance, and use value of cotton carded with and without crush rolls was conducted at Stoneville and processed at the Pilot Spinning Plant at Clemson. Conclusions from the study are:

(1) Card crusher rolls can be effective in reducing and breakage and processing costs and in increasing yarn quality. (2) Changing from conventional to high-production carding, as defined in this study, can result in improved spinning performance, reduced processing costs, and improved yarn quality. (3) Carding rates on the high-production system can be increased without apparent damage to processing performance and yarn quality. (4) There is a need for revisions in the present system for grading cotton. (5) Fiber breakage from gin cleaning can be minimized by careful control of lint moisture content during ginning. This is a confirmation of previous findings of the U.S. Cotton Ginning Research Laboratories. (6) Spinning effects from gin cleaning treatments were small and usually insignificant, within the scope of this test.

Essentially the same results were obtained using Pima cotton ginned at the Mesilla Park Laboratory.

Effect of Cultural and Harvesting Practices:

6. A study of cotton topping carried out in cooperation with Cotton Harvesting Investigations at Stoneville showed that from a gin cleaning, fiber quality, and market value standpoint, there were no important advantages from the various field treatments as compared to the control lots.

Dates of defoliation and picking undefoliated (in the green) were studied at Mesilla Park in cooperation with the Arizona Agricultural Experiment Station. As far as ginning was concerned there were no differences due to field treatment.

7. In cooperation with western cotton breeders numerous strains of upland and Pima cottons have been investigated at Mesilla Park. Research has been conducted to determine the effects of inherent seed and fiber properties on ginning performance. The compiled test results, with emphasis on the laboratory-developed measurement of tenacity of fibers to seed, are reported. With 130 upland samples and 156 Pima samples, results within each species show that relatively low tenacity is significantly related to greater ginning capacity, greater lint turnout, fewer cottonseed linters, higher micronaire readings, fewer neps, and fewer short fibers in the ginned lint. Relationships were not significant between tenacity and fiber length, fiber strength, and seed coat fragments. No adverse effects were found to be associated with the relatively low tenacity of fibers to seeds.

Studies at Clemson showed that at the time a seed roll in the gin stand collapses, the trash to cotton ratio is greater and the color of the lint is lower than when the gin is operating at normal capacity. Also, during normal ginning upper half mean length, mean length, uniformity and short fiber content were lower. Fiber fineness was also lower during normal ginning. These data indicate that a higher percentage of longer fibers are removed from the seed during the initial stages of ginning a lock of cotton leaving the predominantly short coarse fibers to be removed last. This confirms previous studies at Stoneville.

8. Total power consumption for six gin plants surveyed by the Clemson Laboratory ranged from 32.5 to 56.7 kw.-hr. per bale. At four of the six gins, power consumption per bale was less in 1965 than in 1964. At the two gins where power consumption per bale was greater in 1965 than it was in 1964, the ginner reported more rain resulting in intermittant operation during the 1965 ginning season.

A proposal prepared by the Laboratory was partially responsible for a reduction in power consumption at one gin from 70.8 kw.-hr. per bale during 1964 to 56.1 kw.-hr. per bale during 1965. Based on an average cost of 2-1/2 cents per kw.-hr., a savings of 36.75 cents per bale was realized on power costs.

G. Lint Cleaning

1. Lint cleaner tests at Stoneville indicate air washing the grid bar section of lint cleaners does not contribute significantly to cleaning efficiency. The air suction serves only to reduce the lint fly emitted from the lint cleaners thus tending to reduce ambient air pollution within the plant. The tests pointed out that considerable savings may be affected by substituting low-pressure high-volume fans for the high pressure fans normally used for this purpose.

H. Packaging

1. A pilot model packaging device was constructed at Stoneville and subjected to preliminary tests. The tests suggested considerable revision was necessary.

I. Cottonseed

1. Tests for cottonseed quality were run at six selected commercial gins by the Clemson Laboratory. The study indicated lower germination and higher seed damage associated with high capacity ginning. The test lots ginned on the older type low capacity gin produced better quality seed in all categories evaluated.

2. A study of the damage to cottonseed by individual pieces of equipment and combinations of cleaning machines was made at Stoneville. The test showed that mechanical picking contributed 7.3 percent seed damage and the gin stand 7.4 percent, while the intermediate drying, conveying, and cleaning system contributed only 1.9 percent, making a final total of 16.6 percent. The studies also showed a greater degree of damage associated with dry seed. Seed moisture levels for the four series of experiments were 12.2, 16.5, 8.0, and 8.5 percent and corresponding total cottonseed damage percentages encountered through the cleaning and ginning system were 12.7, 13.8, 17.6, and 22.4 percent, respectively. As shown by wagon sample data, this trend of greater mechanical damage to dry seed is also sustained in the process of mechanical picking, before the cotton is brought to the gin.

J. Waste Collection and Disposal

1. Tests at Stoneville showed that lint fly may be effectively eliminated from the discharge of low pressure exhaust fans using fine perforated metal for drum condenser covering in lieu of delicate fine mesh screen wire used in preliminary studies last year. There was no measurable effect on lint quality by using the perforated metal or screen.

Tests at Stoneville showed that lint cleaner waste may be collected with a low pressure fan on a fine mesh screen wire filter. Some dust will pass through the filter thus making it necessary to employ a second filter to

remove the dust so that the air may be returned to the gin building. This series of tests also showed that a filter with moving parts exposed on the trash collecting side of the unit will not operate successfully.

The modification at Mesilla Park of a condenser drum by covering with a fine mesh screen for a filter media and equipping the device with an automatic screen cleaning mechanism gave good results in the collection of lint fly and dust. The unit operated satisfactorily in the laboratory roller gin plant and appears to offer the ginner another method for controlling condenser exhaust air pollutants.

Tests at Clemson showed that the addition of water spray to an experimental inertial separation chamber decreased the amount of pollutant material emitted to the atmosphere from the unloading fan by as much as 65 percent. Within the gin a greater concentration of pollutant material was present in the air during the processing of stripped cotton than was present during the processing of machine picked or hand picked cottons. During alternate processing of machine picked and hand picked cotton, concentration of pollutants within the gin was greatest for machine picked cotton. Microscopic examination of materials removed from the floor of the separation chamber after dry operation revealed sand particles averaged 126 microns, leaf particles 491 microns, fiber particles 984 microns and unidentified seed 2767 microns. In addition to the above, wet operation removed dust particles averaging 18.8 microns and other unidentified particles of similar size.

Preliminary studies made at Clemson for the purpose of developing a technique for measuring air pollution and particulate matter distribution around gins indicated that downwind dispersal and fallout of dust and other gin trash follows theoretical calculations.

A survey by the Clemson Laboratory of selected gins in the Coastal Plains area of South Carolina indicates approximately 65 percent of the total connected horsepower was utilized in materials handling and collection. Generally, only gin motes and/or lint cleaner waste are collected for eventual disposal. Other gin waste is generally discharged directly to open areas, contributing to air pollution.

Tests with a dry type centrifugal separator at Clemson showed that it may be operated either wet or dry and this type of device shows promise as a means for collecting fibrous material and dust from various exhaust systems of the gin. Success of the device is attributed to its ability to agglomerate fibrous material.

A device constructed at Clemson for the purpose of collecting lint particles from the air electrostatically appears to have promise. The device did significantly affect the concentration of particulate matter in the air stream. The air sample readings indicated an average of 31 percent decrease in concentration when the device was on. The weight of material on the

screen indicated a 54 percent decrease and the weight of material on the floor indicated a 40 percent increase when the collector was on. Hence the collector was attracting the lint particles out of the air and agglomerating them before they fell to the floor.

2. A vertical and a horizontal capacitor were built at Clemson to study the electrostatic attractive and repulsive forces on cotton particles in a uniform electrostatic field. The results showed that in a field of 2,270 volts per inch and a relative humidity of 50 percent the attractive force was 10 dynes while the repulsive force was 5 dynes.

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AREA NO. 7. STRUCTURES FOR CROP AND MACHINERY STORAGE AND PLANT GROWTH

Problem. The magnitude and scope of the crop and machinery storage problem is evidenced by the vast quantities of crops and other materials handled and stored on the farm. Annually on the farm: (1) Five billion bushels of corn, wheat, and other grains are harvested and stored, of which nearly one billion is carried over from the preceding year; (2) 208 million tons of hay and silage are processed and stored; (3) nearly 2.5 million bushels of apples and pears and 34 million hundred-weight of potatoes and sweet potatoes are held for food, feed and seed; (4) other large quantities of fruits and vegetables are held for temporary storage pending marketing; and (5) large amounts of fertilizers and feeds are purchased and held in storage pending use. An aggregate total of more than seven million tractors, combines, corn pickers, and other expensive farm machines need storage and repair buildings to maintain operating efficiency.

Farming methods are continually changing, requiring new information to be developed to keep storage structure design abreast of the cropping practices. For example, crops are being harvested, handled, and stored in new forms such as high moisture shelled corn, wafered forage, and low moisture silage.

Plant growth structures can represent investments ranging from a few hundred to several million dollars depending on their nature and scale. Controlled environment growth chambers range from $1000 to $50,000, controlled environment greenhouses from $2000 to $700,000, and phytotrons from $400,000 to $5,000,000. During the last four years, the USDA has spent about $500,000 per year for growth chambers. No overall expenditure figures are available.

The 1959 census showed 227 million square feet of commercial greenhouse area in the United States. Of this area, 83% is used for florist crops, 4% for nursery crops, and 13% for vegetable crops. Greenhouse produced crops equal 2% of all farm products sold.

Recent experience of plant and other scientists concerned with use of plant growth chambers indicates a general inability to closely maintain desired environmental conditions and a lack of means for measuring conditions actually maintained in these units. There is urgent need to develop engineering design criteria for constructing and equipping chambers that will reliably provide and maintain desired thermal, lighting, and other environment over a wide range of experimental conditions. Design criteria for automatically maintaining scheduled environments are needed also for greenhouses and other production type-plant growth structures.

USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in both basic and applied research and the development of typical plans for storage and plant growth structures.

A. Crop Storage Structures (silos and bins). Research is cooperative with Animal Husbandry Research Division, ARS, at Beltsville, Maryland; and with the Iowa Agricultural Experiment Station, Ames, Iowa.

B. Plant Growth Structures (environmental chambers and greenhouses). Research at Beltsville, Maryland, is cooperative with Crops Research Division, ARS.

C. Plan Development. Typical plans for crop structures and related equipment are developed at Beltsville in cooperation with the regional committees representing all State Experiment Stations and Extension Services.

The Federal effort in this research area totals 2.4 scientific man-years. Of this number 1.1 are devoted to crop storage structures; 1.0 to plant growth structures; 0.1 to plan development and 0.2 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

The complicated problems associated with providing protection to the products of agricultural production as well as the machines, equipment, and service facilities which are required for such production has necessitated a continuing program of research at the State Agricultural Experiment Stations.

The current broad scale program is concerned with conditioning and storages for high moisture grains; curing, bulk handling, and storage for onions; curing and storage sheds for tobacco; structural characteristics, wall pressures, design and construction of silos; Irish potato and sweet potato plant production facilities and storages; controlled atmosphere storages and construction methods; design for machinery sheds and farm service buildings; and designs and construction of plant growth chambers and plastic greenhouses.

Much of this research activity is cooperative with the Department.

A total of 9 scientific man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Crop Storage Structures.

1. Silo design criteria. In studies at Beltsville to determine relative effectiveness of gastight tower and bunker silos, farm size silos were filled with similar orchard grass and each was managed by recommended methods. Stored silage densities were nearly equal; feedable silage recoveries were essentially equal, about 92%. No spoilage was recovered from the gastight tower, but the bunker had 3.6% spoilage mostly at the juncture of plastic wall lining and top cover. The bunker had high peak temperatures, but dissipatedless total heat than the gastight tower Preservations of individual nutrients was essentially equal in the 2 silos, implying that temperature variations below 36° C do not affect nutrient loss.

Determination of forage density in normal storage conditions, using a radioisotope, continued at Beltsville, Maryland. In a tower silo filled with wilted alfalfa, density measurement by radioisotope showed that silage directly under the drop point was of nearly uniform density up to within 10 feet of the final surface, while at the opposite side of the silo, density began to decrease within 20 feet of the surface. This shows a packing effect of the dropping forage during filling, and a possibility of increasing overall density. For absolute measurement of density of farm products the radioisotope method has not proved practical as a research tool. A large enough radioactive source requires excessive shielding; instruments are costly and unstable.

Availability of wilted orchardgrass at Beltsville, Maryland, enabled obtaining of a few additional bunker silo wall pressure readings. These will be combined with previously obtained readings for analysis.

2. Wilted grass silage storage. In studies at Beltsville, to determine the effect of chop length on wilted grass silage, 2 farm size concrete silos were filled with similar crop and procedure, except that one mass was chopped short and the other long. Increased silo capacity due to short chopping was less than 5%. Both silage masses gave feedable silage recovery greater than 90% in spite of the forage being very dry, and no definite effect of chop length was found. However, top spoilage was greater in the long chop. Temperatures indicated similar fermentation processes in the 2 masses, but the long chop dissipated more energy as heat. Sealing of silo doors with plastic sheet was adequate for both chop lenghts. A top sealing procedure which extended the plastic cover below the silage surface at the wall was effective but wasteful of labor compared to the usual procedure of turning the cover up at the wall.

In another experiment, a silo filled with alternate layers of long-and short-chopped wilted alfalfa showed no evidence of an effect of chop length on preservation efficiency. However, as a whole, this mass showed a phenomenon not previously associated with silage; A high degree of gas convection. It was evidenced by a marked drying of the central part from movement of water vapor to the wall, where extreme putrefaction resulted; by a uniform oxidized condition of the central part, rather than a spoilage front around points of air entry; and by a separation into 2 distinct hot and cold temperature regions with the hot region extending during storage. This phenomenon may be the most critical factor in non-gastight storage of drier forages.

3. Hay wafer storage. In a resumption of previous studies at Beltsville, Maryland, cylindrical rolled alfalfa wafers were tested for ease of drying in a dual purpose (drying and storing) deep bin. Drying rate was limited by moisture migration within the wafers and was too slow to prevent moldy centers in the wafers for typical conditions in farm driers. This wafer form had slightly better mass breakup characteristics for unloading from a deep bin than did previously tested extruded wafers. Mass air flow rate was slightly greater than that in extruded wafers. An eight-foot depth of cylindrical wafers gave a maximum pressure on vertical walls of 25 lb/sq. ft.

4. High moisture shelled corn storage. No progress during the reporting year.

5. Grain bin pressures. No progress during the reporting year.

B. Plant Growth Structures.

1. Phyto-Engineering Laboratory. Considerable effort was devoted to planning, developing and generally overseeing construction of a new research facility at the Plant Industry Station, Beltsville, Maryland. It consists of a 1-1/2 story building 72' x 36', containing offices, laboratories for engineering and plant physiology studies, and space for construction and testing growth chambers. An 80' x 100' concrete platform for greenhouse research studies is attached to the rear of the building.

The building and facilities will be used to study both engineering and plant physiological problems; hence the name Phyto-engineering.

2. Carbon Dioxide Studies. Studies were conducted on a preliminary basis with CO_2 in gaseous and carbonated water forms during the year to test out new equipment and controls and to develop a sound cultural practice for growing various types of plants in a completely controlled environment. In the CO_2 gas studies seeds of several annual flowers were germinated and grown to the flowering stage. Growth (wet. wt.) in the controlled chambers was as much as 100 times of the same

varieties grown in the greenhouse. In all instances growth was much faster and, for most of the plants, flowering was earlier. Geraniums grown from seed that normally flowers in 18 weeks were flowering in 8 weeks. Petunias normally take 8 weeks or longer, but flowered in 35 days.

Entirely different results were obtained with the carbonated water spray. Studies were made on the same annual flowers and on mum and azalea cuttings. Various spray cycles, light cycles, and root media were used, but none of the tests using CO_2 water were significantly better than those using plain water. In some tests the growth of the plants under the CO_2 enriched water was less than the checks.

3. Motion meter. The motion meter developed previously was further improved by incorporating 10 plant movements sensers through a timed stepping switch to a single point recorder. Each point is recorded one minute out of ten minutes. The system has worked quite well and you can see the pattern of each point as it moves across the chart paper.

4. Greenhouse cooling. Preliminary studies were conducted to develop and test a new technique for greenhouse cooling by moving pre-conditioned air between two layers of greenhouse covering to remove a large percentage of the radiant energy. Tests were conducted on various materials to determine their ability to pass visible light and their capacity to remove infra-red radiation. Solar radiation was assimilated by using reflector incandescent lamps. Early results indicate that from 1/3 to 1/2 of the radiant energy of incandescent light can be removed while reducing the light only 10-20%.

5. Portable greenhouse. A temporary, self-contained, portable greenhouse was developed to provide a temperature and humidity controlled area in a remote portion of a pear orchard at the Plant Industry Station, Beltsville, Maryland. The facility was needed by the Crops Research Division to meet a requirement of 70°F temperature and high humidity for inoculating pear seedlings with fine blight bacteria. A fan and pad system is used to keep the humidity at a high level. In addition, spray nozzles are used inside the greenhouse to further increase the humidity and to wet the plants. A bottled gas motor generator furnishes electric power for the fan and pumps. Water is supplied by a tank that has to be filled periodically. The generator is started manually early in the morning when water supply and other equipment is checked, and shuts off automatically at a preset time. It has worked quite well and shows great promise for similar applications.

6. High temperature greenhouse. A high temperature (100°F) greenhouse for virus treatment, constructed for the Crops Research Division at Beltsville, Maryland, about 2 years ago in accordance with design guidance furnished by this project has functioned fairly well except for air distribution which caused minor hot spots. Since the plants are held just below their lethal temperature any hot spot will cause plant damage. Blowers were installed under the growing tables to circulate the air at 15 air changes per minute. Humidity is automatically controlled by injecting steam into the air stream.

C. Plan Development. At Beltsville, Maryland, plan for a basement type plant growth chamber for the homeowner was redesigned and working drawing nearly completed under the title "Plant Growth Chamber Roomette,"Plan No. 5980.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Crop Storage Studies

Simons, J. W. and Hare W. W. 1965. Grain Drying and Storage Studies in Southwest Georgia. USDA Technical Bulletin 1342. November.

Menear, J. R. and Holdren, R. D. 1965. Handling, Storing and Drying Wafered Hay in Humid Areas. Transactions American Society of Agricultural Engineers.

PUBLICATIONS -- STATE EXPERIMENT STATIONS

Hunter, J. H., and Toko, H. V. 1965. Control of Potato-Storage Diseases as Affected by Air Flow, Temperature and Relative Humidity. Trans. of the ASAE. 8(4), pp. 578-580.

Isaacson, J. D. and Boyd J. S. 1965. Mathematical Analysis of Lateral Pressures in Flat-Bottomed, Deep Grain Bins. Trans. of the ASAE.8 (3)

Lorenzen, Robert T. 1965. A Balancing Technique for Moisture Control in Structural Components of Controlled-Atmoshpere Storages. Trans. of the ASAE. 8(4), pp. 505-507

Marshall, McNeil, and Massey, P. H. 1965. Plastic Greenhouse Design for Lower Costs and Good Plant Environment. Agricultural Engineering 46(6) pp. 322-323,324.

Neubauer, L. W., Hoyle, B. J., and Kucera, E. 1965. Effect of Methods of Storage on Subsequent Growth and Yield of Seed Potatoes. Trans. of the ASAE. 8(1) pp. 138-140

Walker, J. N. 1965. Predicting Temperatures in Ventilated Greenhouses. Trans. of the ASAE 8(3), pp. 445-448

Zahradnik, J. W., Perry, J. S., and Fang, T. Y. A. 1965. Long Term Performance Evaluation of an All-Plywood C-A Storage. Trans. of the ASAE, 8(3), pp. 443-444.

AREA NO. 8 RURAL DWELLINGS

Problem. The 1960 Census of Housing indicates that although about 500,000 new farmhouses were built between 1950 and 1960, rural housing as a whole continues to be older than and inferior to urban housing in condition and value of buildings and in availability of plumbing, heating, and labor-saving equipment. Large numbers of houses outside of cities and towns remain without the convenience and comfort features of typical urban homes.

Housing costs are still a major obstacle for farm families that wish to make improvements for themselves or to furnish better housing to attract and hold qualified and reliable tenants or workers, either full-time or seasonal. Costs are also a problem for the rural non-farm family. Continuing research is needed on ways to reduce costs through better use of space and improved application of old and new materials and use of more efficient construction methods. The Farmers Home Administration program or rural housing loans needs research support to provide designs that will meet modern housing standards at moderate cost and be sound and desirable security for 30-year government loans. Further research is also needed on design and equipment of houses for improved control of temperature, air movement, and economy of operation and maintenance.

With the rapid increase of the non-farm population in rural areas outside of villages, including many elderly and retired people, more attention should be given to their housing. People who have vegetable gardens and garden equipment to store, and who live on small acreages, drawing water from wells and using septic tank sewage disposal systems, have housing problems similar to those of farmers, and the housing research of the Department is applicable to them. Engineering research on design of equipment for senior citizen housing is also needed.

Programs for bringing in foreign agricultural workers to supply the short term peak labor needs associated with many of our farm crops, particularly fruits and vegetables, have expired. These labor needs are now being filled predominately with domestic seasonal and migratory workers. These domestic agricultural workers tend to travel in family groups more than did the foreign workers and thus have changed the pattern of housing requirements. In addition, public health agencies are concerned that the housing provided for these workers be adequate and sanitary so as to reduce the hazard of spreading disease - among themselves, or among residents of communities in which they work, through contacts with the crops they are handling.

There is also a trend toward community - and grower associations camps, with greater child care, health service and semi-skilled job training programs incorporated.

An individual producer is concerned that his facilities be as inexpensive as possible in order to hold down his production costs and maintain his competitive position. In view of this, there is need for research to develop design criteria for adequate housing and related facilities for these workers and their families, particularly where the term of occupancy is short - 2 to 4 weeks per year.

USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in both basic and applied research and the development of typical plans and planning guides for rural dwellings of all types. A program of evaluation and development of construction plans and utilization of low-cost housing for seasonal and migratory farm workers is being conducted for the U.S. Public Health Service under a reimbursable agreement dated March 22, 1965.

A. Design Criteria for Comfort, Health and Safety. Research at Athens, Georgia, on determination and evaluation of thermal and sound effects of soft window and floor coverings, is in cooperation with the Georgia Agricultural Experiment Station. Development of planning aids at Athens, Georgia, is cooperative with the Georgia Station.

B. Materials and Construction. An experimental structure for developing and evaluating low-cost floor deck and slab construction is located at Plant Industry Station, Beltsville, Maryland. Prototype low-cost houses have been constructed at Charles Town, West Virginia, to evaluate new design features.

C. Systems for Environmental Control. A study to determine the optimum arrangement for an attic fan to reduce summer temperatures economically is underway in Athens, Georgia, in cooperation with the Georgia Station. Experimental low-cost plenum warm air heating systems are being evaluated in prototype houses at Charles Town, West Virginia.

D. Rural Housing Design Development. Architectural design and preparation of farmhouse plans for the Cooperative Farm Building Plan Exchange and related publications are carried on at Beltsville, Maryland, in cooperation with the Federal Extension Service. The State Agricultural Colleges cooperate through Regional Committees in establishing housing requirements and State Experiment Stations make the plans available to the public. Farmers Home Administration consults on requirements and also make plans available to its clients. The Public Health Service, USDHEW, is cooperating in development of designs for housing facilities for seasonal and migratory agricultural workers. The Federal effort

in this research area totals 6.4 scientific man years. Of this number 1.4 are devoted to design criteria for comfort, health, and safety; 0.9 to studies of materials and construction; 0.6 to systems for environmental control; 2.9 to development and preparation of improved rural housing designs; and 0.5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 13.3 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Design criteria for comfort, health and safety.

1. Thermal Control. The laboratory study of the affect of window and floor coverings on heat transfer and environmental factors of dry bulb temperature, radiation and air motion is continuing at Athens. Tests have been run with a fixed glass panel and with lined draperies of four different fiber contents. Tests included normal drapery installations and drapes sealed at top, bottom and sides. A test is being run currently with an ordinary roller shade. Preliminary data indicate that closed drapes per se have but small effect on heat transfer through the window area, as the cooled air between the glass and the drapes flows downwardtoward the floor causing cold drafts. Although statistical analyses have not been made, observed differences in heat flow using materials differing in fiber contact appear to be insignificant. Sealing the drapes on sides, top and bottom, reduced the heat flow by 20%.

2. Noise Control. In the cooperative laboratory study at Athens by the Georgia State Experiment Station and AERD twelve different types of acrilan, cotton, nylon and wool carpets and these types of underlays (mats) have been tested for sound characteristics in the reverberation room. Tests have been run at an initial maximum noise level of approximately 85 decibels found by previous studies in occupied homes. The frequencies covered by the tests include the extremes normally disturbing to the average human. All carpets were tested without underlays and with the three different underlays. The data have been taken off the charts and coded for computer analysis. Sound absorption and noise reduction coefficients will be computed and significance of differences due to fiber content, pile height and type of surface determined.

Similar tests were also run in the reverberation room on four different drapery materials--cotton, fiberglass, rayon and rayon acetate. The data will be taken off, coded and analyzed statistically in a manner similar to that underway on carpets.

A preliminary computation comparing heavy weight (43 oz. per sq. yd.) Acrilan plain loop carpet and the same weight of plain loop wool carpet using 32 oz. hair-jute underlay under both carpets showed that Acrilan had 50 percent higher sound absorption coefficients at 250 and 2,000 cycles per second. At 8,000 cps the coefficient for wool was 50 percent higher than Acrilan. Coefficients for both carpets without underlay were so low as to be insignificant at 125 and 250 cps and were generally considerably lower up to 2,000 cps than with the 32 oz. hair-jute underlay indicating the importance from a noise reduction standpoint of using underlays. If room noise spectra produce anything like the equal loudness measurements obtained for simple tones, the range from 750 to 5,000 cps is of special importance in the reduction of noise levels. The wool with 32 oz. underlay showed much greater variation in absorption coefficients than Acrilan. On the basis of the above observations Acrilan would be somewhat more effective than wool.

3. Planning Aids. Preliminary drafts have been completed on the following House Planning Aids: (1) Foundations and Walls; (2) Wood Framing; (3) Selecting Exterior Coverings; (4) Making Basements Dry; (5) Summer Cooling For the Farmhouse; (6) Residential Carports and Garages; (7) Post-and-Girt Wall Framing for House.

B. Materials and Construction

1. Low-cost floor deck and slab studies. Test flooring utilizing wood product underlayments for asphalt tile placed above a vapor barrier protected earthfill has now been in place for 2 years and 9 months at Beltsville, Maryland. A periodic record of moisture in and under the flooring materials has been kept throughout the test period. To date there has been no apparent build-up of moisture or indication of decay. Excess water applied to the floor has caused very slight warpage near the edges of the test panels.

2. Prototype low-cost house construction. The use of pole type construction for houses is being studied in a second test house which was designed and constructed at Charles Town, West Virginia. This structure is 32' x 24' and two stories high. It incorporates an experimental pole frame which acts as a retaining wall to support the earthfill which is about five feet deep around the first floor of the house. The pole frame was covered outside with pressure treated plywood in direct contact with the earth backfill. This house also included two circulation plenums as part of the heating system; one is under the basement floor and the second one is built into the joist space between the first and second floors. Experimental construction features will be observed in service to obtain performance data.

3. Manuscripts. A manuscript was prepared for a Production Research Report on an economical house framing system. A major revision of FB 1572 was prepared to bring it up to date and add material on dehumidifiers and sump pumps.

C. Systems for Environmental Control

1. Attic fan cooling arrangements. Tests were run during the summer of 1965 to determine the optimum arrangement and operation of the attic fan in relation to the placement of insulation. Similar tests ran in the summer of 1964 gave somewhat comparable results. The beneficial effects of forced ventilation cannot be totally measured by temperature reductions alone because of the cooling effects of air motion over the body. However, the following conclusions are based on observations of the averages:

1. Forced ventilation by means of the attic fan give a slight temperature advantage over natural ventilation without fan operation.

2. With windows closed in the morning and open in the afternoon and night and with the fan ventilating the attic in the afternoon and the rooms at night a slight temperature reduction resulted as compared with windows open 24 hours per day. The same result might not be obtained where large glass areas are exposed to the morning sun.

3. Ceiling insulation resulted in lower inside air temperature than roof insulation with the attic ventilated in the afternoon and the rooms at night.

4. With the ceiling insulated there was a very slight temperature difference in favor of ventilating the attic in the afternoon and the rooms at night as compared with ventilating the rooms only at night. The difference probably would not justify the additional equipment and automatic or manual control necessary to ventilate the attic in the afternoon.

2. Warm air heating plenum. In an effort to extend the use of plenum heating (heat distribution) to most types of structures a plenum system was developed for and built into a two story house at Charles Town, West Virginia. It incorporated a plenum under the downstairs floow and a second plenum in the space between the two floors. A centrally mounted fan and a vertical duct can supply air to or take air from: (1) the upstairs living area; (2) the plenum between the floors; (3) the downstairs living area and (4) the plenum under the basement floor. Air delivery to the living area from the plenum will be through a narrow slot along the outside wall. Performance data will be obtained during the next heating season.

3. Manuscripts. A major revision was prepared for MP 689, " Your Farmhouse Heating," to bring costs up to date and to include descriptions and illustrations of the newer heating devices and systems. Manuscript was prepared for a Production Research Report on Heating low-cost homes.

D. Rural Housing Design Development

1. Farm and rural dwellings. Four farmhouse plans, were released during the past year, two 3-bedroom, one 2-bedroom, and one 5-bedroom. Working drawings on the single-story (research) house of pole and panel construction build at Charles Town, W. Va., are nearing completion. The plan will be included in the Plan Service.

Eight miscellaneous publications describing farmhouse plans were issued during the reporting year. Two others are in press and seven in various stages of preparation.

2. Seasonal and migratory agricultural worker housing. An extensive study was made of all state and federal sanitary and housing codes available pertaining to migrant labor housing as a basis for developing improved designs of migrant labor sanitary facilities and housing. An intensive search country-wide for plans of migrant labor housing revealed almost negligible information. Thus there was little basis on whish to develop new plans, except Farmers Home Administration requirements and observations of existing camps in the main migrant labor streams.

Contacts are continuing with a number of grower organizations in Colorado, Florida, New Jersey and Oregon to develop cooperative projects whereby prototype migrant labor camps based on our housing designs will be built by organizations or growers and evaluated by ARS and PHS. Individual grower cooperators are also being included particularly for construction and test of multipurpose designs and of non permanent designs that will meet the need to provide flexibility for the growers who are unsure of their future labor needs or who desire to avoid problems of transportation and competition for labor from a "central" camp.

E. Household Equipment.

1. Nevada - Acceptability of Portable Cooking Appliances by the Elderly. Thirty-five people (three men and thirty-two women), from 58 to 90 years of age, participated in a comparison of portable electric cooking appliances with a standard-size range. The appliances used were: a two burner hot plate, a toaster-over and a hot plate. Each person twice prepared a complete meal, using the portable appliances one day, and the standard range the next. A majority indicated preference for the portable appliances. When acceptability was based on rating

of specific appliances, 77% preferred the portable appliances; when based on subjective choice, 63%. Ease of use and economy were the most significant factors relating to acceptability. Age, income, education, and number of appliances owned were not significant influences. Little difference was noted in the quality of meals. These results demonstrate the economic and space saving advantages of such appliances in housing for the elderly.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Design Criteria for Comfort, Health, and Safety

Mize, J. J., Tuten, F., Simons, J. W. 1966. A Study of Sound Levels in Family Houses. Journal of Home Economics. January 1966

Systems for Environmental Control

Simons, J. W., Parker, W. Russell. 1965. Control of Direct Sunlight for Comfort. Miscellaneous Publication No. 995. July

Simons, J. W. 1965. Heating. The Yearbook of Agriculture. Consumers All.

Simons, J W. 1965. Cooling the House. The Yearbook of Agriculture Consumers All

Biggs, Archie A. 1965. Fireplaces. The Yearbook of Agriculture Consumers All

Rural Housing Design Development

Parker, W. Russell. 1965. Multi-Unit Retirement Housing for Rural Areas. Agriculture Information Bulletin No. 297. August

Parker, W. Russell, Taube, R. Katherine. 1965. Planning for Safety. The Yearbook of Agriculture, Consumers All

Agricultural Engineering Research Division. 1965. Three-Bedroom Farmhouse. (Exchange Plan No. 7174). Miscellaneous Publication No. 997. June.

Agricultural Engineering Research Division. 1965. Three-Bedroom Farmhouse - Brick Veneer Construction. (Exchange Plan No. 7171) Miscellaneous Publication No. 998. June.

Agricultural Engineering Research Division. 1965. Three-Bedroom Farmhouse - pole and panel construction. (Exchange Plan No. 7164) Miscellaneous Publication No. 999. June.

Agricultural Engineering Research Division. 1965. Solar-type Farm Cottage. (Exchange Plan No. 7148). Miscellaneous Publication No. 1001, July.

Agricultural Engineering Research Division. 1965. Three-Bedroom Farmhouse - masonry construction. (Exchange Plan No. 7170) Miscellaneous Publication No. 1006. October.

Agricultural Engineering Research Division. 1965. Two-Bedroom Farmhouse - masonry construction. (Exchange Plan No. 7172). Miscellaneous Publication No. 1007. November.

Agricultural Engineering Research Division. 1965. Three-Bedroom Farmhouse. (Exchange Plan No. 7169.) Miscellaneous Publication No. 1008. November.

Agricultural Engineering Research Division. 1966 Three-Bedroom Farmhouse. (Exchange Plan No. 7165). Miscellaneous Publication No. 1010. February.

Agricultural Engineering Research Division. 1966. Three-Bedroom Farmhouse. (Exchange Plan No. 7167). Miscellaneous Publication No.1011. February.

Tayloe, Genevieve, O'Brien, Constance, and Parker, W. Russell. 1965 Workrooms, Miscellaneous Publication No. 1002. August.

Biggs, Archie A. 1965. Housing for Seasonal Farm Workers. Agriculture Information Bulletin No. 296. April.

PUBLICATIONS -- STATE EXPERIMENT STATIONS

Design Criteria for Comfort, Health and Safety.

Ehrenkranz, F. 1965. Functional Convenience of Kitchens with Different Sink-Dishwasher Locations. J. Home Econ.

Indiana Agricultural Experiment Station. 1965. Farm House Requirements and Their Application in the Improvement of Farm Housing. State Research Bulletin 798. NCR Research Publication 164.

Materials and Construction

Day, S., and Shamburger, E., 1965. Factors Affecting Skid Resistance of Resilient Floor Coverings. J. American Hosp. Assoc. April

Systems for Environmental Control

Philson, K. 1965. Temperature and Humidity Effects of Cooking Pot Roasts. Virginia Agricultural Experiment Station Bulletin 562

AREA NO. 9. LIVESTOCK ENGINEERING (EXCEPT ELECTRICAL)

Problem. The American farmer has about $14 billion invested in service buildings and related structural equipment, over half of it for livestock facilities. Maintenance and new construction amount to another $1.2 billion annually, again mostly for livestock facilities.

Economic conditions are forcing changes in the pattern of livestock production. Producers are trending toward fewer, larger and more specialized enterprises and toward "confinement" types of facilities in their effort to reduce production costs and improve product quality. These trends are demanding more basic knowledge about the effects of environment on the health, growth, production and fertility of livestock; about structures and related equipment for maintaining desirable environments; and about methods, structures and equipment for more efficient handling and feeding. The continuing threat of nuclear warfare demands consideration of types of buildings that will provide protection from fallout for livestock and their feeds, and provide facilities for operation during periods of emergency.

Much more needs to be learned in the laboratory on the relationships between livestock environment and disease transmission, feed conversion rates, and growth and production in order to determine optimum environments. Structures and equipment for economically providing these optimum environments under practical conditions need to be developed and field tested. Closely associated with the environment are flies and other insects, as well as parasites and diseases, that sap the vitality of animals and reduce their productivity. Pesticide residues in animal products are causing much concern. Information is needed on means for keeping these residues from adversely effecting the animals or their products.

Labor is an important element in production costs, and if only family labor is available, the labor requirement limits the size of enterprise. How to adapt existing buildings and other facilities for more efficient production, as herds and flocks are increased in size, or as farms are consolidated, is a major problem area. Cost of replacement or major improvement of existing buildings that are not suited to modern production methods are serious obstacles. Principles, examples and techniques for planning more efficient operations are needed both by farmers doing their own engineering and by those on whom farmers depend for advice.

Many types of structural and handling equipment such as feed bunks, self-feeding silos, and feeding floors, are important to livestock production enterprises. Adaptations and improvements to keep design of such equipment abreast of current production practices and buildings are essential to producers.

USDA AND COOPERATIVE PROGRAM

This is a continuing program involving engineers and architects conducting basic laboratory investigations, application of laboratory results to a production basis, and development of typical plans for livestock structures. The work is in cooperation with the Animal Husbandry, Animal Disease and Parasite, and Entomology Research Divisions of ARS, USDA, and is a contributing project to Cooperative Regional Research Project NE-8, "Essentials of Poultry Housing for the Northeast." Plan development work is cooperative with all the State Colleges through Regional Committees, and with FES, as part of the Cooperative Farm Building Plan Exchange.

A. Dairy Cattle Engineering. Dairy cattle environmental and bioengineering studies are conducted in a climatic laboratory at Columbia, Missouri, in cooperation with the Dairy Husbandry and Agricultural Engineering Departments of the Missouri Station. AH, ARS, serves in an advisory capacity. The influences of building arrangement, equipment, and chore routines on the amount and drudgery of dairy chores and means of improving these factors are studied in cooperation with the California Agricultural Experiment Station. Typical plans for dairy structures are developed at Beltsville, Maryland.

B. Beef Cattle Engineering. Beef cattle structures and equipment research for hot, dry climates is conducted in cooperation with the California Agricultural Experiment Station at the Imperial Valley Field Station, El Centro. Typical plans for beef structures are developed at Beltsville, Maryland.

C. Swine Engineering. Swine structures and equipment research for hot, dry climates is in cooperation with the California Agricultural Experiment Station at Davis and for hot, humid regions at Tifton, Georgia, in cooperation with the Georgia Costal Plain Experiment Station and AH, ARS, on an "occasional visit" basis. Typical plans for swine structures are developed at Beltsville, Maryland.

D. Poultry Engineering. Poultry house environmental design criteria are investigated in controlled-temperature laboratory studies at Beltsville, Maryland, in cooperation with AH, ARS, and the basic laboratory data are applied to experimental poultry houses of the NE-8 Regional Project for evaluation.

Limited field studies on relation of housing structures to poultry disease are conducted in Mississippi in cooperation with the State Agricultural Experiment Station and AH, ARS. Environmental influences on health and housing requirements are investigated in new laboratories at Athens, Georgia, and State College, Mississippi, in cooperation with AH and ADP, ARS, and the respective State Agricultural Experiment Stations. At St. Paul, Minnesota, a study of the role of environment in the prevention and control of chronic respiratory disease in turkeys is underway in

cooperation with the Minnesota Agricultural Experiment Station. Typical plans for poultry structures are developed at Beltsville, Maryland.

E. Livestock Shades and Shelters. Shades for sheltering livestock are being studied at Davis, California and Tifton, Georgia, in cooperation with the respective State Agricultural Experiment Stations.

F. Sky Radiosity Studies. Studies of sky radiosity (total radiation) are conducted at Davis and elsewhere in California, and at Columbia, Missouri, in cooperation with the respective Agricultural Experiment Stations.

G. Reducing Pesticide Residues in Animal Products. Reduction of pesticide residues in animal products, with beef cattle receiving major attention, is studied at Kerrville, Texas, in cooperation with ENT and ADP, ARS, and the Texas Agricultural Experiment Station.

Federal research effort in this area totals 9.5 scientific man-years. Of this number 2.2 is devoted to dairy; 0.7 to beef; 1.6 to swine; 3.4 to poultry; 0.0 to livestock shades and shelters; 0.4 to sky radiosity studies; 1.3 to reducing pesticide residues in animal products; and 0.7 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

There is an extensive program of both basic and applied research underway at the State Agricultural Experiment Stations in an effort to provide the answers to the continuing series of questions being raised by livestock producers. Demands are being made for more information on the effects of environment on the physical well-being of all classes of livestock, and the way such optimum environments can be economically achieved; on new approaches to meet the growing labor shortage; on methods to adapt existing structures and equipment for greater economy of production; and on structures and related equipment for improved efficiency of feeding and materials handling operations.

Studies are being made on the effect of environment on the health, growth, production and fertility of dairy cattle, beef cattle, poultry and swine. Equipment and systems for efficiently transporting feedstuff into and out of storages and automatically mixing and feeding complete rations are being developed.

Exploring methods for improved care and housing of farm animals with greater economy and labor efficiency are also in progress as well as investigation of ways to modify existing structures and equipment to meet present-day economic conditions.

Much of the work is cooperative with the Department.

A total of 27.0 scientific man-years effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Dairy cattle engineering

1. Increasing efficiency of operations. At Davis, California, studies to determine the effectiveness of herringbone milking parlors in reducing the labor requirement in large-scale dairy enterprises were continued in cooperation with the State Agricultural Experiment Station. Time and travel studies have been made on milking operations in a total of 64 herringbone layouts, 10 of them during the reporting year. Findings during the year confirm those indicated previously which are: (1) herringbone milking parlors are just as satisfactory for milking large herds (1000 cows or more) as for small; (2) herds can be milked faster (on a man-minutes per cow basis) in a herringbone parlor, with the same effort, than in any other type of milking layout -- assuming proper arrangement, good routine, and good equipment in proper adjustment; (3) herringbone layouts cost no more, and in some cases less, (on a per milking stall basis) than other types of elevated stall layouts; (4) herringbone layouts have little or no advantage over other types of elevated stall layouts for herds of less than about 35 cows; and (5) some operators place the milking machine on the cow between her hind legs, instead of from either the right or left flank, and believe this suspends the machine from the udder at a more natural angle. Results are being prepared for publication.

Preparation of a manuscript on facility layouts covering several years' study has been completed. Some of the principles covered have already been used as the basis for technical papers and other publications.

Farmstead planning, covering overall farmsteads, is discussed in Area 10 E.

2. Bio-engineering studies. Basic fundamental studies on the relationships between environment and various dairy animal health and production factors were continued in the psychroenergetic laboratory, and related facilities, at Columbia, Missouri, in cooperation with the Missouri Station.

Studies of inspired-air modification for lactating Holstein dairy cows were continued during the year. The current study is to determine the effects of reducing total heat content of the inspired-air by dehumidification as opposed to the temperature reduction method previously reported. Subjecting the cows to a room environment of 85°F and a high humidity (90 to 95 percent R.H) while supplying low humidity air (25 to 35 percent R.H) at the same temperature for breathing purposes resulted in marked reactions in milk production, feed consumption, rectal temperature and respiration rate. When the inspired-air humidity was increased to the high level while the room humidity was held low, the reactions for all except respiration rate were affected to a lesser extent; respiration rate increased. All the results indicate high humidity room environment to

have a more detrimental effect on heat dissipation than high humidity inspired-air. This study substantiates the previous inspired-air cooling investigation, as results of both studies have shown it is possible to markedly alter the heat dissipation by lactating Holstein cows by changing the total heat content of the inspired-air. Neither method of altering total heat content (by cooling or dehumidification) of the inspired-air will produce the benefits of cooling or dehumidifying the total environment, however.

Preliminary investigation of continuous flow metabolism measurements for lactating Holstein cows indicated such a system to accurately reflect the effects of environment and other factors on the metabolism of large animals.

The study comparing an air-conditioned dairy barn with a dry-lot confinement system was continued during the summer of 1965. Two groups of 16 cows were used in the switchback design (3-week treatment periods, with three reversals). Results of this second test season agreed with the first season's results: highly significant (1 percent level) differences occurred in rectal temperature and milk production, with the air-conditioned barn providing the more favorable environment in both cases. Analysis of dairy cow activities under the controlled-environment and dry-lot confinement systems for the 2 years indicated only small differences in the total amount of time spent at specific activities for the two systems. However, the diurnal distribution of the activities was quite different.

Heat sensitivity studies on mature dairy cows continued during the summer of 1965. Observations made on lactating Holsteins held in a 43°C (107.6°F) environment until a 1°C (1.8°F) rise in body temperature had occurred showed significant correlation between cows (99% confidence level) and between rate of milk production decline and rate of rectal temperature rise (95% confidence level), and no trend of rectal temperature use with season.

3. Plan development. At Beltsville, Maryland, in cooperation with the Northeastern Regional Plan Exchange sub-committee on dairy housing, the following plans were developed:

Plan No. 5977, "Dairy Housing Equipment, Permanent Type." This plan was originally developed by Massachusetts.

Plan No. 5985, "101 Cow Free-stall System," originally developed by Connecticut.

Plan No. 5987, "Liquid Manure Tank."

Plan No. 5981, "Rectangular Concrete Manure Tank." (Also in cooperation with the Portland Cement Association).

Plan No. 5984, "Circular Concrete Manure Tank." (Also in cooperation with Portland Cement Association)

B Beef cattle engineering

1. Hot, arid climates. These investigations are conducted at Daivs, California, and at the Imperial Valley Field Station (El Centro) of the University of California, in cooperation with the Departments of Animal Husbandry and Agricultural Engineering of the California Agricultural Experiment Station.

The 35x75 ft. laboratory at the Imperial Valley Field Station was completed early in 1966. It consists of three working rooms (animal operating room, machine and control room, and feed storage room) and an animal laboratory 25x75 ft. The latter room is fitted with 12 individual, removal pens 4-1/2x 12 ft. There are three separate concrete manure pits 18x21 ft. under the pens; the pits are covered with concrete slats. A 15-ton refrigerating unit has been installed which, at present, has only simple air temperature thermostats controlling the compressors. During the summer of 1966, the operation of the laboratory will be checked out with a single comparison of beef cattle gains and feed utilization in a 75 to 80°F temperature to those of beef cattle raised in the normal out-of-doors summer environment.

Effect of shade height on physiological responses of beef cattle was studied at Davis and El Centro. Three 8x12 shades 6,9, or 12 ft. high and so spaced that their shadows would not overlap were constructed at Davis and El Centro. Four halter-broken steers were used in a latin square design with one animal kept at the center of the shadow of each shade (and one in the sun) during each of four days at Davis. Respiration rate, pulse rate, surface temperature (thermocouple) and rectal temperature (rectal thermometer) measurements were made, one for each animal, once each hour from 10 a.m. to 5 p.m., on July 28, 29, and August 2,3 1965. The animals were then moved to El Centro and after two weeks acclimation, they were put through a test identical with the one at Davis. The El Centro Tests were conducted on August 16, 17, 18, and 19. Ping-pong black-globe thermometers were kept at the centers of the shadows of the shades, and one was always in the sun. Other hourly measurements included wind velocity, relative humidity, air temperature, and horizontal surface radiation (Eppley normal-incidence radiometer). The radiant heat load was lowest under the high shade and highest under the low shade (clear sky, low humidity). Shade significantly (P .01) reduced rectal temperatures, respiration rates, and surface temperatures of the steers; also, all were generally higher under the low shade and lowest under the high shade.

Study of sloping floors for beef cattle feedlots, started in 1963 at El Centro to investigate the manure removal problem in beef cattle feedlots, was continued. During the summer of 1965 four sloping floors were used (concrete floors 12x14 ft. with a slope of 4.75 degrees, or

about 1 inch per ft.). Pits 6 ft. wide were built on the lower end of two of the floors and covered with concrete slats. On one pen the feed bunk was at the lower end so the animals stood on the slats to eat; on the other three it was at the upper end. A water flushing system was installed at the upper end of one of the two floors that did not have the pits. There were six steers on each floor with an area of about 40 sq. ft. per animal. Six animals in a fifth pen (dirt) had about 120 sq. ft. per animal. The test started on June 7 with steers averaging 751 lbs., and was concluded August 11 when the steers averaged about 983 lbs. Manure accumulation on the lower part of the sloping floors was less than in the previous year; considerable manure still accumulated at the upper end. Flushing prevented this accumulation, and a flushing system combined with sloping-slotted floors might be feasible. Activity studies showed that steers seldom stood or lay on the slotted floor. The gains and efficiency on all floors, except the sloping floor without slats or flushing, were very good, but the differences were not statistically significant. Animals continued to be rather dirty, but this fact did not seem to affect gains or carcass grade. The slotted pit performed satisfactorily and was remarkably free of odor and fly larvae.

Cooled drinking water for cattle was investigated at El Centro. Past tests within this project showed there was an advantage, in terms of animal weight gains and feed conversion rates, for beef cattle drinking 70°F water rather than the 90°F water usually available at the pens in El Centro during July, August, and September. Tests were initiated during the summer of 1965 with various water temperatures for the purpose of defining more closely the best temperature of drinking water (or the amount of cooling required). A total of 8 pens was used (15x45 ft. with 15x16 ft. shade) with 4 treatments. Two pens each of six steers constituted one treatment. The treatments were 60, 70, 80, and 90°F drinking water temperatures. A 3-ton central water chiller was used for a supply of cold water that was circulated through a copper-coil exchanger in each water tub. The waterers were concrete tubs, 30 inches deep and 36 inches in diameter. They were covered except for a small opening through which the animals could drink. The test ran from June 30 to October 6, 1965. As of the reporting date the detailed data on animal sizes, etc., were not available at Davis. The overall results, however, are summarized below.

Water temperature °F	90	80	70	60
Av. daily gain lb.	3.41	3.30	3.24	3.28

Cooled water showed no effect on weight gains, but there were some complicating factors in the equipment used for chilling the water. This test will be repeated in the summer of 1966.

Beef cattle shades were studied at Davis to establish the requirement for shade for beef cattle there. The experiment began June 15 and ended October 12, 1965. The treatments were shade and no shade, with three

replications. The animals were randomly assigned to seven groups of 10 each and then to six identical, completely concrete surfaced pens. The seventh group was slaughtered immediately to establish initial body composition. All cattle were slaughtered at the end of the trial. Carcass specific gravity was the essential parameter used to calculate energy retention during the feeding period. Each pen provided 320 sq. ft. (40x80 ft.) of space per animal and the 12x24 ft. shade in the center of each shaded pen provided about 29 sq. ft. of shade per animal. Approximately 510 hours of air temperatures were over 29.5°C (85°F) during the summer. This is 100 hours less than the five year (1961-1965) average of 613 (Davis, California) and 280 hours less than the highest value recorded during the period averaged. Shade had no beneficial effect on any of the measured criteria for response.

Winter stalls for beef cattle were investigated at Davis. The six shade units (12x12x10 ft high) used during the summer were modified with adjustable legs (8 and 10 ft. height) and removal stalls (six stalls per 12x12 ft. shade unit). Three of the six concrete pens (40x80 ft) were each provided with two shade units (12x12x8 ft. high) and each shade unit having six stalls (40"x5'-6"). The other three pens were not provided with shelter or stalls. Nine animals were assigned at random to each of the six pens on November 2, 1965 (initial wt. 476 lbs. av.), and the study terminated on March 22, 1966 (final wt. 895 lbs. av). The average daily gain and feed conversion is as follows:

Stalls					
Date	11-30	12-28	1-25	2-22	3-22
ADG	2.83	3.25	3.12	3.07	2.98
F/lb. G.	5.46	5.39	5.81	5.99	6.24
No Stalls					
ADG	3.16	3.50	3.16	3.07	2.99
F/lb. G.	5.19	5.22	5.89	6.15	6.37

There was no difference in the rate of gain or feed conversion of the animals in the above treatments, but the animals in stalls were much cleaner.

2. Hot, humid climates Inactive during reporting period.

3. Plan development. At Beltsville, Maryland, in cooperation with the Southern Regional Plan Exchange, Plan Number 5991, Beef Cattle Corral, 50 head was approved and issued for national distribution.

C. Swine Engineering. Swine environmental studies were conducted at Davis, California, in cooperation with the Animal Husbandry and Agricultural Engineering Departments of the California Agricultural Experiment Station. These include studies on humidity effects and swine moisture loss measurements in a controlled laboratory, and field tests on swine exercise and ultraviolet lights. Tests were continued at

Tifton, Georgia, in cooperation with the Georgia Experiment Station. This was the final year for tests relating the use of sprinklers under shades to reproduction of sows and gilts and growth of market hogs.

1. Effect of humidity on swine . Study of influence of humidity on growth rate and feed utilization of swine was continued in a controlled laboratory at Davis. Two additional humidity tests were completed in the chamber during the year. These are Tests IV and V, summarized below. To briefly review, three separate rooms were installed in the psychrometric chamber. The dry bulb temperature and dew point of each room can be individually controlled. Three Durocs are put into each at the beginning of the test, and they usually weigh about 80 lbs. The humidity was either 45, 70, or 95% in all except Test IV when the humidities were maintained at the optimum prescribed from results of previous tests on this project. In Test IV, the dry bulb temperature was 10°F above the optimum. The pigs had a floor area of about 8 sq. ft. per pig and the air flow rate (3 changes/minute) was about 10 ft. per minute. The results for this year's tests (Test IV and V), as well as for past tests, are summarized below.

Test	Dates	D.B Temp.	Humidity 1/		
			Low	Medium	High
			Av. daily gain, lb.		
II	12/17/63-3/25/64	Opt.	1.56	1.48	1.41
III	12/10/64-3/18/65	Opt.	1.57	1.42	1.56
IV	6/16/65-9/14/65	10° above Opt.	1.33	1.30	1.12
V	12/19/65-3/23/66	Opt.	1.59	1.54	1.45
				Lb. feed/lb. gain	
II	-	Opt.	3.71	3.67	4.16
III	-	Opt.	3 .49	3.67	3.06
IV	-	10° above Opt.	3.52	3.56	3.65
V	-	Opt.	3.56	3.48	3.70

1/ Low, medium and high humidities for Test IV were 30, 60, and 90%; for all other tests, 45, 70, and 95%.

There has been little apparent effect of humidity when the dry bulb temperature was near optimum except that the differences in daily gain approached significance (P 0.05) in Test V. With the higher dry bulb temperature IV the humidity effects, or at least the effects of the 90% relative humidity, were stronger. Additional tests at higher than-optimum temperatures are needed and are planned for the coming year. Surface and rectal temperatures have been measured regularly.

2. Sprinking for hot, humid climates. Study of the influence of sprinkling pigs and sows in a hot climate was continued at Tifton, Georgia. Sows and gilts; Four one-acre, temporary pasture lots were

used, each with two shade units. In two of the lots, each shade unit had two fog nozzles (Monarch #4.6160, 2.3 gal/hr at 25 psi) mounted 8 ft. apart and 3 1/2 ft. above the ground, directed down. The sprinklers were on from 8 a.m. to 7 p.m. Eight bred animals in each lot were started on test May 4, 1965, and were moved into the farrowing barn on July 28. Two of the four lots (one with gilts and one with sows) had shade and sprinklers. The other two lots (one with gilts and one with sows) had shade only. Fog nozzles located under the shade during the summer gestation period did not affect reporduction performance of gilts and sows. This was the fourth year of this study and it will be terminated. Pigs: In 1965 the environment under movable shades was modified by use of an electric fan blowing air lengthwise under the shade on the pigs. The fans were 36" in diameter (11,000 cfm). The test was started May 11 with 10 Duroc pigs per lot averaging 48.4 lbs. each. Two lots had shade (12x16 ft.) and one fan each and two lots had shade only. After 87 days (pig weight 200 lb) there were no significant differences in daily gain or feed consumption between the two treatments.

3. Swine exercise. Swine exercise experiments have been conducted for several years in an effort to evaluate possible means of increasing certain of the more expensive muscle cuts of pork, such as the hams and loins. Two phases of this work were conducted during the reporting year.

a. Treadmill: A treadmill was constructed so that 4 or 5 pigs could eat at stand-up feeders while their back legs were on the treadmill. The pigs had to walk on their hind legs while eating. For the first trial, February to April 1965, the comparison group used with the treadmill group ate at an elevated feeder like the one the treadmill group ate from. The pigs were fed twice a day so the treadmill was on for two periods a day, for about one hour each time. For the second trial July 14 to September 13, 1965, the pigs were restricted to 8 sq. ft. per animal and were fed individually twice per day. The pigs were removed from the test when they were 200 lbs. A control group was group-fed in a trough at ground level. A second control group was similar to the test group (standing to eat) but did not use a treadmill. No measurable effects were observed in either test. Muscle samples were taken from all slaughtered pigs and analyzed by Veterinary Medicine. Results of these analyses are not yet available.

b. Walking: This study was made to observe the effect of exercise on rate of gain and eating habits of swine. It was started on January 17, 1966, and ended on February 14. Two pens in the hog barn were used. One pen had 8 pigs which were exercised twice daily about 9 a.m. and 4 p.m. by running and/or walking twice to the end of the outside alley (about 10 minutes per two trips). Eight pigs in the other pen were not exercised except for weighing. After two weeks, the lowest pigs in the exercised group and two pigs in the other (lowest weight) were removed from the

test. The four-week gains are shown below:

Pen	ADG - lbs 2 weeks 8 pigs	ADG - lbs 4 weeks 6 pigs	Feed/gain 2 weeks 8 pigs	Feed/gain 4 weeks-6 pigs 2 weeks-2 pigs
Exercise	0.90	1.37	5.90	4.34
No exercise	1.59	1.62	4.25	4.18

Pigs were marked on the backs so that the position of each pig in the pen was known. The activity cameras (single frame movie at 10 minute interval were mounted overhead of each pen and ten 24-hour periods were analyzed (January 19, 20, 24, 25, 26, and February 1, 7, 10, 11, and 14). It was assumed that the pig was in the position indicated on the film for 10 minutes in the data given in the table below. (Only pigs remaining to the end of the test were included.)

The influence of exercise is evident in the table above which shows that the exercised pigs gained at a slower rate. The table below shows that the exercised pigs spent more time lying down and less time eating.

Activity of pigs with and without exercise (walking), Davis, California

Exercise Pen

Pig No.	Total gain lb.	Percent of time lying	eating	standing (incl. eat)	stand,no eating (by substraction)	
145	16	93.0	6.5	7.0	9.5	Difficult to walk
59	38	87.6	9.0	12.4	3.4	Difficult to walk
74	70	86.8	9.4	13.2	3.8	
151	46	86.1	8.8	13.9	5.1	
16	36	85.1	11.7	14.9	3.2	
162	54	82.6	11.5	17.4	5.9	Moved out freely
Mean	38.3	86.87	9.48			

No Exercise Pen

Pig No.	Total gain lb.	Percent of time lying	eating	standing (incl. eat)	stand, no eating (by substraction)
48	36	88.6	6.9	11.4	4.2
73	50	85.9	8.8	14.1	5.3
18	48	83.6	11.7	16.4	4.7
89	52	82.8	11.2	17 2	6.0
152	44	81.3	11.7	18.7	7.0
130	42	78.5	13.5	21.5	8.0
Mean	46.3	83.45	10.63		

The difference in mean time lying is almost significant. For the exercised pen the correlation coefficient between gain and standing time is 0.98. No correlation for the other pen.

4. Moisture loss. Study of skin and lung moisture loss from swine was continued at Davis. Tests were made to determine, as accurately as possible for swine, (1) the moisture loss at a moderate and at a high temperature at constant dew point; (2) the effect of dew point or vapor pressure on moisture loss at a relatively high temperature; and (3) the relative importance of the respiratory system and skin as sources of water loss. A pig was trained to be in a cage of expanded metal within a rigid plexiglass enclosure through which air was blown: Lithium-chloride-type dew point measuring devices were used in the inlet and exit air streams. Air velocity past the pig in all tests was about 5 fpm, but the volume was such that there was a rise of only about a degree in dew point as air passed through the enclosure.

The entire apparatus and also housing for the pigs were located in a controlled environment chamber. During the first half of a run, total moisture loss was measured; a mask over the pig's snout served only to catch saliva. A small blower within the enclosure supplied fresh air for breathing by means of a flexible tub attached to the mask. For the second half of the run, flexible tubes were connected to the mask so that air was brought from, and exhausted to, the outside of the enclosure, thus enabling skin moisture loss to be measured.

The table below shows a summary of data from the last tests (2 Duroc gilts, 198 lb).

TEMP. °F		RH%	Moisture Loss, Grams/Min/Pig		
DB	DP		LUNGS	SKIN	TOTAL
60	50	70	0.28	0.38	0.66
85	50	30	0.87	0.72	1.59
85	64	50	1.12	0.59	1.71
85	74	70	0.78	0.86	1.64
85	82	90	0.41	0.83	1.24

Skin moisture loss ranged from 35 to 67 percent of the total amount vaporized. With a change in air temperature from 60 to 85°F, at constant 50°F dew point, the pigs were able to offset the decrease in sensible heat loss by doubling the skin loss and tripling the lung loss, the latter by means of tripling the volume rate of respiration. At constant 85°F air temperature with dew point increasing from 50 to 82°F (30% to 90% RH) skin loss remained nearly constant and lung loss actually increased then decreased. Skin loss, usually about half the total loss increased to two-thirds at 85°F DB - 82°F DP

5. Ultra-violet radiation. Effect of ultra-violet radiation on swine

was studied at Davis. Three tests have been completed to measure the effect of ultra-violet radiation on weight gain and feed utilization. Two tests were conducted at the hog barn and a third was conducted at the Stralock Farm. At the hog barn, one Sterilamp (30 watts, 2537 Angstroms) was hung about 10 feet above the center of each of six 10x13 ft. pens holding 5 pigs each (5 treated pens in Trial 1 and 6 treated pens in Trial 2). The pigs were on concrete floors, had automatic waterers and self-feeders. The number of check pens was equal to the number of treated pens in each case. The lamps were on all the time except when someone was cleaning the pen. In the test at Stralock, a group of 24 Duroc pigs were fed individually (twice per day) in two 9x24 ft. pens. Twelve of the pigs were exposed to six "Sterilamps" (30 watts, 2537 Angstroms) mounted 9 ft. above the floor of one of the two pens. There have been no effects of ultra-violet radiation in any of the three tests. The results are summarized in the table below.

	Ultra-violet light		Control	
	Av. Daily gain lb.	Feed/lb. gain	Av. Daily gain lb.	Feed/lb. gain
Trial I 12/14/64 to 2/10/65 5 pigs/pen	1.42	3.15	1.42	3.26
Trial II 6/23/65 to 8/18/65 5 pigs/pen	1.39	3.81	1.35	3.83
Trial III 1/3/66 to 3/14/66 12 pigs/pen	1.70	3.76	1.65	3.80

6. Plan development. At Beltsville, Maryland, in cooperation with the Southern Regional Plan Exchange, Plan No. 5986, "Part Slat Feeding Floor for 200 Pigs," was developed and published for national distribution, and at the request of the Southern Regional Plan Exchange Committee, Plan No. 5993, "Shed Type Farrowing House or Farrow to Finish Unit," developed by North Carolina, was included in the Plan Exchange. The plan shows eight pens with removable farrowing stalls. Length of the building may be varied in units of 12 feet (two pens). Pole-type construction is specified. Also at Beltsville, but in cooperation with the Western Regional Plan Exchange Plan Number 5988, Swine Feeder, which was originally designed by Montana was modified, developed and published by the Plan Exchange for distribution nationwide.

D. Poultry Engineering

Poultry house environmental design criteria were investigated in controlled-temperature laboratory studies at Beltsville, Maryland, in cooperation with AHRD. Environmental influences on health and housing

were investigated in the Southeast Poultry Research Laboratory, at Athens, Georgia, in cooperation with ADP and AH (ARS) and the Georgia Agricultural Experiment Station and in the South Central Poultry Research Laboratory at State College, Mississippi, in cooperation with AH and ADP (ARS) and the Mississippi Agricultural Experiment Station. Criteria for design of heating, ventilation, and air conditioning equipment for turkey production were investigated at St. Paul, Minnesota in cooperation with the Minnesota Agricultural Experiment Station. At Davis, Califonria, studies were continued to determine the influence of air ion polarity on poultry (Japanese quail.) in cooperation with the Poultry Science Department.

1. Calorimeter studies at Beltsville. Heat and moisture data from broilers, along with other biological data necessary for designing a broiler house and its ventilation system, were partially developed. Studies of growing broilers from hatch to 35 days of age showed that brooding may be started at air conditions of 86°F and 75% RH, or at 94°F and 50% RH. Small chicks averaging near 30 grams required at least 91°F and 75% RH. After a period of brooding, the maximum live weight of broilers was obtained at air temperatures between 65° and 75°F. Surprisingly, the rate of respired moisture production in per pound live weight, for any given average weight of broilers was nearly constant for all temperature levels between 57±2 and 84±2°F. Calculations show that 1000 broilers averaging 0.5 pound will respire 55 pounds of water per day, while a similar number of 4 pound broilers will respire 130 pounds. Further calculations show that the amount of water in the fecal matter for 1000 four pound broilers at 9 weeks of age and at 41°F and 68°F amounts to 350 and 290 pounds per day respectively. Chicks averaging 0.5 pound will produce 62 pounds. Broilers averaging 0.5 pound lost 40 percent more sensible heat in per pound live weight at 57±2°F than at 84±2°F. When broilers averaged 4 pounds, there was 25 percent more heat loss at 57±2°F than at 84±2°F.

It is planned to develop the engineering application and to check these laboratory data in an experimental broiler house at the University of West Virginia.

Winter studies of turkeys showed that 31-month old females averaging 11.5 pounds panted at 80°F and 65% RH, while 7-month old males averaging 22.5 pounds panted at 73°F and 63% RH. These temperatures appear to be lower than those at which they pant in the summer. In per pound live weight units, the 22.5 pound males respired slightly less than did the 4 pound broilers at temperature between 55 and 73°F. At 80°F these turkeys respired moisture at about the same rate as the broilers. Similar data showed that the 11.5 pound non-laying female turkeys respired at about 1/2 the rate of 4-pound broilers at temperatures between 55 and 73°F, and at 80°F slightly less than the broilers.

The rate of sensible heat production in per pound live weight units, was

1/2 to 2/3 of that for broilers averaging 4 pounds. The fecal production rate of the hens averaged 0.5 pound per day at all temperatures studied, while the males differed -- 0.73 pound at 55°F, 0.48 pound at 73°F and 0.67 pound at 81°F. For both sexes the fecal moisture content was close to 80 percent. Four additional tests should be conducted in the summer to obtain data reflecting seasonal change on adult male and female turkeys.

No studies on laying hens were conducted during the reporting year. Plans are underway to equip the five environmental chambers to study bird density and high and low energy diets in wire laying cages.

2. Southeast Poultry Research Laboratory. Engineering activity at this recently completed facility is largely still concerned with development, procurement, and installation of test equipment and instrumentation for the engineering portions of contemplated multi-discipline research programs.

During the report year, two additional prototype environmental cabinets, with control panels, were completed and performance-tested. Currently four cabinets with control panels have been completed, together with planning and installation of hot and cold liquid supply systems. The four cabinets are of similar construction, although not identical in all details. Provision has been made for programming temperature of air (both dry bulb and dew point), of each sidewall separately, of the top surfaces, and of the bottom. In addition, air circulation may be regulated within each cabinet, and the quantity of air exhausted can be regulated and adjusted. Automatic feeders with convenient height adjustment have been installed, and automatic waterers with height adjustment, overflow, and flush cleanout have been constructed and installed. In addition, a rotary table for work surface was installed in each cabinet. Two refrigeration units have been installed to provide cold liquid to six cabinets. (Two more cabinets are contemplated to complete installation of this unit.) Two gas-fired water heaters have been installed for hot liquid supply. The four environmental cabinets with all necessary components had been in operation for about two weeks (as of the reporting date)-both with and without chickens-and so far appear to be functioning adequately.

In addition to the four cabinets in operation, work was completed on another prototype cabinet of somewhat different design. Both cabinet and control panel differ appreciably from those now in use. Cabinet construction is considerably simplified, several controls eliminated, and both labor and time requirements reduced considerably.

3. South Central Poultry Research Laboratory Engineering research to determine by experimental procedures the effects of construction, equipment and management of poultry housing structures on broiler diseases and condemnations has been initiated at this newly constructed facility

in cooperation with AH and the Mississippi Station. Initial work is being conducted in four research poultry houses on the laboratory farm and is concerned principally with the influences of insulation and brooding equipment on selected environmental factors associated with the economics of poultry production. Early studies show:

Broiler houses with insulation installed and with our management practices have given some advantages over the noninsulated broiler houses in average weight, feed efficiency, mortality, and brooding cost, but gave a disadvantage in condemnation loss.

Using part of the broiler house as a starting pen or brooding area for the baby chicks appears to be desirable, with brooding costs reduced from the present system of using the entire house for brooding as well as growing.

It is desirable to have an air space between metal roofing and insulation and this air space vented at eave and ridge so as to reduce metal surface temperature as well as heat intake into the house during high temperature periods. Using the roof surface to condense excess mositure out of air during low temperature periods appears to be feasible and practical to reduce heat loss to the building.

A constant low (40°F) room temperature does not appear to increase broiler condemnation as much as a diurnal fluctuation from 40°F to 80°F.

4. Field observations on relation of housing to disease in broilers in the South Central States. Work in Mississippi, in cooperation with AH and the Mississippi Station has continued at a reduced pace. Two comparable houses on a commercial broiler producer's farm, both having insulation in the roof and winch-adjusted woven plastic curtains on the sidewalls, were studied to compare fan versus natural ventilation. Fans were controlled by thermostats and time switches - natural ventilation was manually controlled. Data are not yet available.

5. Influence of turkey housing environment on disease. The relation of turkey disease and environment is studied at St. Paul, Minnesota. The last seven experiments in the Environmental Turkey Building have been on the effectiveness of Tylan dipped turkey eggs in eliminating the transmission of N strain PPLO through the egg. The first flock resulted in disease-free birds at market age. The present flock (No. 7 in this building) is also disease free.

During these studies a data acquisition system has been under development. Temperatures, and wind direction and velocity are now being recorded. As sensors for other data are obtained, or devised, an environment monitoring system with computer analysis of data will be completed.

Diseases other than those under study have gained entry into the facilities. Blackhead did not develop in pens with concrete floors. With one type of E-coli an infra-red lamp brooder possibly facilitated early eating of medicated feed which resulted in low mortalities compared to commercial brooders. Studies indicate the need for structural and equipment improvements.

6. Ion polarity effects. The effects of ion polarity on poultry are under study at Davis, California. The possibility that air ions might be an environmental factor influencing growth are being investigated, using Japanese quail (coturnix japonica). In the studies, an environment with a preponderance of negative ions or positive ions was compared with one of natural ion distribution as to effects on rate of growth, mortality and sexual maturity. Three enclosed brooder-housing chambers were used, each 3ft. by 4 ft. by 16 inches high. Each chamber was heated with a fan-type electric heater with a thermostat. One chamber was equpped with a negative-ion generator and a second with a positive-ion generator: Approximately 60 one-day-old Japanese quail were placed in each chamber at the start of each test. The temperature was 100°F for the first week and was lowered 10°F each succeeding week. The period of maximum growth for Japanese quail is at about 3 weeks of age, hence studies of growth were discontinued at 4 weeks.

During the first four tests, the ion generators were operated continuously; during the next two tests the birds were given a 12-hour-light and 12-hour dark schedule with ions provided only during the lighted period for the first test and only during the dark period the second test. In the last three of the 9 tests all chambers had only natural-ion conditions for the first six days, then the generators were on continuously. In tests 1 thru 4 (ions from the first day) there was s significant (5% level) weight depression when the birds were subjected to high densities of negative ions. With ions provided only during dark hours, the negative-ion group grew less than the positive-ion group but more than the "natural" group For the first six tests combined, there was a highly significant (1% level) reduction in growth due to negative ions. When the artificial ion environment was delayed until the quail were six days old, the results were less consistent.

7. Eggshell thickness. Studies of eggshell thickness measurement by means of radioactive isotopes have been initiated at Beltsville, Maryland. This is the first report concerning this work. During the first year of the project it was found that the attenuation or absorption method of measuring shell thickness was unsatisfactory due to the great absorption of the interior of the egg. After research at both Oak Ridge National Laboratory and Beltsville and intervisits by researchers from both laboratories, it was decided to use a B emitter and measure the energy bounced back to an annular Geiger-Mueller tube around the source. A thick shell will bounce back more of the particles whereas a thin one will allow more of them to go on into the egg. Since an eggshell is thicker than most of the films previously measured by this B back-scatter technique, it was decided to start with the most penetrating B source commonly used, i.e., strontium 90. This source proved not strong enough. ORNL then fabricated a more energetic B source consisting of ruthenium 106-rhodium 106. Tests conducted jointly with ORNL personnel indicated it was possible to determine the shell thickness to 001 inch using this technique; but it required ten minutes per egg. Another source

has now been fabricated using more of the same isotope. This should reduce the measuring time to one minute. Further research is expected to make more reductions in measuring time.

8. Plan Development At Beltsville, Maryland, in cooperation with the Northeastern Regional Plan Exchange sub-committee on poultry, Plan No. 5978, 40' Nailed Truss for Caged Layers was placed in the Cooperative Plan Exchange for national distribution. Also at Beltsville, Maryland, in cooperation with the Southern Regional Plan Exchange Committee, Plan No. 5990, Laying House, was developed. This pole-type building is insulated and provided with both mechanical and natural ventilation. Slatted floors are used over the dropping pits under the feed and water troughs. The 40 by 96 foot building may be lengthened in units of 16 feet.

E. Livestock Shades and Shelters. Reported under 9-B-1, 9-C-2, and 9F.

F. Sky Radiosity Studies Radiant fluxes from the sky, ground and surroundings are being measured at Davis and other points in California and at Columbia, Missouri, in order to evaluate the radiant environment of livestock out-of-doors.

The "short"and "long" wavelength radiation around shades of different heights was measured at Davis and El Centro, California. The two-radiometer system developed last year was used again during the summer of 1965. With this system two directional thermopile radiometers are used (Gier and Dunkle Instrument Co.) One is covered with a quartz filter so that it measures only energy of 5 microns or less. The other measures total incoming flux. The difference between the two measurements provides a measure of long-wavelength radiation (greater than 5 microns). Hourly scans were made under 8x12 ft. galvanized steel shades 6 ft. and 12 ft. high at Davis and at El Centro. Scans were made in the four cardinal directions, at 15-degree intervals from the zenith to 15 degrees below the horizon. Scans were made from 9 a.m. to 3 p.m. on July 23 and September 13 at Davis, and on August 12 and September 7 at El Centro. In addition to hourly scans with the two directional radiometers, the direct-beam solar radiation normal to a surface at the ground was measured with an Eppley normal-incidence radiometer, and solar radiation on a horizontal surface was measured with an Eppley 180° pyrheliometer. For the clear-sky, low-humidity conditions in which these data were obtained the following conclusions were indicated:

1. The diffuse solar energy reflected from the under side of a shade to an animal underneath is considerable, and is greater from a high shade than from a low one.

2. The percentage of short wave energy in the total radiation from shaded ground differed from that in the radiation from unshaded ground at both Davis and El Centro, as indicated in the tabulation:

	% short wave energy in total radiation from: unshaded ground	shaded ground
Davis, Calif.	29	7
El Centro, Calif	23	7

3. The total radiant energy received by an animal under the center of a low shade is less than that received by an animal under the center of a high shade. When the animal is at the center of the shadow of the shade, the influence of the shade height is reversed.

4. Shades 6 feet high reduced the upper hemisphere irradiation on a horizontal surface by about 47% at Davis and by about 51% at El Centro by cutting off the direct-beam solar radiation.

A "ping-pong ball" black-globe thermometer was developed at Davis, Calif., for measuring radiant heat loads under and around shades. These black-globe thermometers were made from table tennis balls. They are only about 1-1/2 inches in diameter, compared with the 6-inch diameter copper spheres previously used. They were coated with Parson's black lacquer (emissivity 0.98) and their temperatures were monitored with 24-gauge thermocouples at their center. These globes are lightweight, small, and inexpensive.

Equations were developed for their use and their response time was studied. The globe equation is: $RHL = 0.232\sqrt{V}\ (t_g - t_a) + \sigma T_g^4$ RHL = radiant heat load, Btu/hr ft^2; V = velocity of air, fpm; t_g & t_a are globe and air temperatures, respectively, deg.F. This same equation was also developed for the metric system.

When exposed to an air velocity of 400 fpm, the smaller instrument responds twice as fast (4.5 versus 9 minutes) as the 6 inch copper globe. At a low air velocity of 30 fpm the difference is less (17 versus 22 minutes) A graph was developed so the response time could be determined for any set of conditions.

G. Reducing pesticide residues in animal products.

Studies of methods and equipment for reducing the chemical hazards associated with control of livestock insects were continued at Kerrville, Texas in cooperation with ENT and ADP.

Earlier studies indicated that successful horn fly control might be obtained with 1 ml. of 10% ronnel applied to the withers of cattle. A series of tests was conducted comparing the effectiveness of a 50 ml. (0.25% ronnel) treatment from an 8-nozzle sprayer with that of a 1 ml. (10% ronnel) treatment from a 1-nozzle sprayer. In large cage tests both treatments resulted in horn fly control (1 ml. average 92.9% and 50 ml. average 98.6% mortality 24-hr. posttreatment). The first of two things

which may explain higher mortality with the 50 ml. spray is that the 50 ml. treatment contains a slightly larger amount of active material (50 ml. X 0.25% = 0.125 gms. active versus 1 ml. X 10% = 0.10 gms. active). Secondly, at one point during the tests the 1-nozzle sprayer was found to be delivering only 0.5 ml. rather than 1 ml. The results of these tests indicate that a sprayer which would consistently deliver 1 ml. of 10% ronnel to the back or side of an animal each day might afford successful horn fly protection.

Development and testing of automatic cattle sprayers was continued with emphasis on frequent low-volume applications since this procedure provides a means of reducing insecticide residues in meat and milk. Two types of low-volume automatic sprayers were used in field studies during the past year. One type employed a small electric air compressor and applied about 100 ml. of 0.1% Ciodrin from 8 nozzles. Although subjected to severe testing on a 300-cow dairy herd, this sprayer has continued to prove itself in ruggedness, dependability, and effectiveness. The second type sprayer to be field tested was an ultra-low-volume sprayer which dispensed approximately 1 ml. of insecticide (10% ronnel) from a single pneumatic atomizing nozzle. This sprayer used precompressed oxygen for pressure and a storage battery for automation. Although laboratory studies indicate that it is possible to obtain horn fly control with a 1 ml. spray of 10% ronnel, field tests and residue tests were only partially successful with this sprayer. Problems were encountered when crystallization of the spray formulation at the nozzle tip caused partial clogging. In an attempt to overcome some of the problems encountered with this 1 ml. pneumatic atomizing sprayer, a new 1 ml. sprayer was developed. This ultra-low-volume sprayer utilizes a device for measuring the quantity of insecticide to be dispensed through the single nozzle. It is self-contained and void of electricity, using pre-compressed air for pressure. Laboratory observations have shown it to be very consistent in its output, which can be varied from 1 to 5 ml. Field tests and residue tests are planned for this sprayer in 1966.

A study was begun to determine the significance of hair loss from cattle as a factor contributing to insecticide loss. Initial work has indicated that hair loss may not be significant from this standpoint. A new procedure was devised to eliminate confining the cow and thereby expose her to more natural conditions. Data collection from this method will continue through 1966.

Preliminary work with the instrumentation system for detecting and evaluating the responses of stable flies, horn flies, and face flies to various physical and chemical stimuli has indicated that it is possible to obtain a continuous flight activity record of these insects. One plan for this system is to determine the daily activity patterns of the insects and thereby determine the best time for insecticide application. Another possibility is its use for screening chemical stimuli which may later be used in application techniques. Several tests utilizing the systems are planned for 1966.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Dairy Cattle Engineering.

The following cooperators' publications are the results of cooperative work and report related non-engineering phases of the research:

Yousef, M. K., and Johnson, H D. 1965. Some blood constituents of dairy cattle: Influence of thyroxine and high environmental temperature. J. Dairy Sci. 48:8 pp. 1074-1078.

Kibler, H. H. 1965. Mercury avoidance in collecting and displacing gas samples. J. Dairy Sci. 48:405, 406.

Johnson, H. D. 1965. Chapter 6 - Response of animals to heat. Meteorological Monographs. 6:28, July p. 109-122.

Yousef, M. K., and Johnson, H. D. 1965. Time course of thyroxine I^{131} disappearance rates in cattle during exposure to hot and cold environments. Life Science. 4:pp. 1531-1543.

Yousef, M. K., and Johnson, H. D. 1965. Helmet for continuous sampling of exhaled air of cattle. J. Dairy Science. 48:1, pp. 104-106

Yousef, M. K , and Johnson, H. D. 1965 (Abst.) Feed and temperature effects on thyroid activity of cattle. J. Dairy Sci. 48:6, p. 813.

Kelly, F. A. Martz, and Johnson, H. D. 1965. (Abst.) Effect of environmental temperature on the volatile fatty acid (VFA) content of rumen fluid from cows receiving constant feed intake. J. Dairy Sci. 48:6, p. 819

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PUBLICATIONS -- STATE EXPERIMENT STATIONS

Swine

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Bell, E. S., Marshall, McNeil, Stanley, J. M., Thomas, H. R., and Kelly, R. F. 1965 Temperature-controlled swine housing: Weaning to Market. Trans. of the ASAE 8(4), pp. 545-547, 557

Butchbaker, A. F., and Shanklin, Milton D. 1965. Development of homeothermic regulation in young pigs. Trans. of the ASAE, 8(4), pp. 481-485.

Poultry.

Bragg, D.D., and Luckham, W. R. 1965. Comparative egg-production costs of layers housed in conventional and controlled-environment buildings. Trans.of the ASAE 8(4), pp. 486-487, 490.

Grub, W., Rollo, C.A., and Howes, J.R. 1965. Dust problems in poultry environments. Trans. of the ASAE, 8(3), pp. 338-339, 352.

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Oliver, E. F., Shove, G. C., and Harshbarger, K. E. 1965. Photographic technique for recording animal-feeding data. Trans. of the ASAE 8(4), pp. 562-564, 571

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AREA NO. 10. CONSTRUCTION STANDARDS, WATER SUPPLY, WASTES DISPOSAL, AND FARMSTEAD PLANNING

Problem. Farm buildings inventoried at $28 billion in the United States are the production, storage (and sometimes the processing) centers of food and fiber for the nation. Annual cost of repair, remodeling and new construction of the farm plant amounts to $2 billion, an expenditure that may wastefully use materials through lack of sufficient knowledge of the loadings to which buildings are subjected--the pressures of soil movement, wind gusts, snowfalls, and stored product loads.

Construction may be wasteful because we lack knowledge of design methods for inherently strong shapes such as hyperbolic paraboloids. Our knowledge of materials and materials fastening is incomplete and often inaccurately used in special applications encountered in livestock production.

Product application research stimulates the economy of manufacturers of building products (lumber, steel, cement, plastics, asphalts, aluminum, inorganics), building fabricators, farm producers and the general consumer. Research is needed on loads imposed on buildings by nature; properties of materials for strength, weathering, aesthetics and durability; and the proper combination of materials of construction for the most economical and effective structures.

In many localities urban building codes that may be unduly restrictive are being extended to cover farms, where the hazards of public occupancy and damage to the property of others are not present to the degree that they are in urban areas. Those who draft building and fire codes need design information that would be realistic for farms.

Recent action programs involving recreational facilities in rural areas need to be supported with plans for sound, workable structures and other facilities such as cabins, boat landings, shelters, etc. There is also need for plans for roadside stands and similar farm marketing structures in support of rural area development programs.

An adequate supply of satisfactory water is essential to the farmstead. Automatic running-water systems, more water-using equipment, new uses for water, higher standards of sanitation, and other factors are continually increasing the demand for water on the farmstead--both in quantity and quality. The "old well" and under-sized distribution system are less and less able to satisfy the demand. Some farm operators have been forced to buy water by the tank or truck load at considerable cost; others are developing farm ponds as sources of farmstead water; some continue to operate with a supply that is becoming less and less adequate.

Surface waters normally require disinfection to guard against water-borne diseases such as typhoid, dysentery, other gastro-intestinal disorders and infectious hepatitis. Often they also require filtration and other treatment to remove undesirable foreign material. Deeper ground waters are often highly mineralized (hardness, iron, sulphur, and others), and expensive or impossible to treat adequately. Pesticide chemicals occasionally show up in farmstead water systems. Data on water demands and water systems requirements of the modern farmstead are needed to guide farmers in planning water systems and selecting equipment, to enable extension workers to adequately advise farmers, and to guide equipment and appliance manufacturers and sanitary code-making bodies. Simpler, more reliable, and less costly methods and equipment are needed for treating farmstead water supplies to improve their quality.

Disposal of organic wastes--principally manures and sewage--is becoming more and more of a problem on the modern farmstead. The cattle, hogs, horses, sheep, and poultry on farms and in feedlots in the United States produce more than 2 billion tons of manure annually. The problem is particularly acute with respect to confinement-type livestock operations on the fringes of metropolitan areas--where the total amount of manure is concentrated in the confinement area, odors and dusts are generated and land areas for disposal are remote. Under these conditions, it is difficult to avoid creating a sanitation hazard or a public nuisance. Economical, sanitary means of disposition need to be developed. Among means that need to be investigated are lagoons, irrigation systems, subsurface absorption systems and reclamation. Development of improved methods for disposing of sewage in those rural areas where conditions are adverse to the conventional septic tank system (high ground water, shallow rock, non-absorptive soils, restricted areas) is needed.

The arrangement plan of the farmstead has an important bearing on its efficiency, appearance, and livability. For example, convenient locations for feed and bedding storage ease the distribution chores. A 40-cow dairy herd will use approximately 240 tons of silage, 60 tons of grain, 40 tons of hay, and 20 tons of bedding annually. Research is needed to evaluate the various planning factors in the light of current equipment and practices and to develop planning principles and guidance materials for the benefit of farmers--particularly those contemplating changes.

USDA AND COOPERATIVE PROGRAM

This is a continuing long-term program involving engineers and architects engaged in basic and applied research on structural aspects of farm buildings, farmstead water supply, farmstead wastes disposal and farmstead planning. The program is cooperative with selected State Agricultural Experiment Stations and other appropriate agencies.

A. Meteorological. Factors affecting the design of farm structures, such as climate and weather (wind, storms, frost, etc.) are studied at Beltsville, Maryland and selected field locations.

B. Construction Standards, such as serviceability and safety, for design of farm buildings are studied at Beltsville, Maryland, and selected field locations. Liaison is maintained with the American Society of Agricultural Engineers, American Standards Association, National Safety Council, National Fire Prevention Association, and other organizations concerned with standards and safety in farm structures.

C. Materials and Construction Methods for farm buildings are studied at Beltsville, Maryland; at Blacksburg, Virginia, in cooperation with the Virginia Agricultural Experiment Station; and at State College, Mississippi, in cooperation with the Animal Husbandry Research Division and the Mississippi Agricultural Experiment Station.

D. Water Supply and Wastes Disposal for the farmstead are studied at Beltsville, Maryland; College Park, Maryland, in cooperation with the Maryland Agricultural Experiment Station, and Watkinsville, Georgia. Liaison is maintained with SWC (ARS) the Public Health Service, the Water Systems Council, the American Society of Agricultural Engineers, and other organizations concerned with rural sanitation.

E. Farmstead Planning studies are made at Beltsville, Maryland, at St. Paul, Minnesota, in cooperation with the Minnesota Agricultural Experiment Station, and at Davis, California, in cooperation with the California Agricultural Experiment Station.

F. Fallout Protection work for the farmstead is conducted at Beltsville, Maryland, and selected field locations. Liaison is maintained with the Office of Civil Defense, Department of Defense, and other appropriate agencies.

The Federal effort in this research area totals 7.3 scientific man-years. Of this number 1.1 is devoted to meteorological factors; 0.6 to standards for serviceability, safety, etc.; 2.0 to materials and construction methods; 2.0 to water supply and wastes disposal; 1.0 to farmstead planning; 0.0 to fallout protection; and 0.6 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

Research in this area is confined largely to basic and applied studies of structural components for farm buildings; techniques and systems for adequate and safe water supply; and improved methods for economical and sanitary disposal of organic wastes on the modern farmstead.

Representative of the investigations currently in progress in the farm

buildings field are those which are concerned with analysis, design and testing of rigidly connected frames and panels; studies of single cover stressed skin designs for clear span roofs; development of wall and roof designs to resist storm damage; tests of the structural stability of farm buildings under accelerated cycles of loading and adaptations of new construction techniques to problems of farm service buildings and animal shelters.

In the water supply area research is underway to develop ways to economically filter and treat surface waters in order to provide an adequate and sanitary quantity of water for the farmstead operations. Studies are also being made on the problems concerned with demineralizing deeper ground waters.

A widespread research effort is in progress which is attempting to investigate all of the factors involved in the complicated problems concerned with disposal of farm waste materials, particularly concentrated manures resulting from confinement-type livestock operations. The problem is most acute and the public is demanding a fast solution to this unsanitary and potentially dangerous health hazard.

Much of the work is this area is cooperative with the Department.

A total of 34 scientific man-years of effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Meteorological factors

At Blacksburg, Virginia, in cooperation with the Virginia Agricultural Experiment Station, dynamic wind pressures are being measured on a full scale test structure that can be quickly rotated to present different exposures to the wind. Instrumentation has been perfected to accurately record pressures and pressure changes that occur in one one-hundredth of a second.

A power spectral density type of analysis is proposed for giving a reasonable technique for describing these loads. This gives the energy output of the wind in relation to the frequency (cycles per second) of occurrence of the energy. This technique is proposed as a method of gust analysis for the American Standards Association to use in designing for wind gusts (Committee ASA 58.1) Sufficient data have not been analyzed to presume any statements regarding the validity of values for wind loading that are currently used for design of buildings.

Frequency of dynamic pressure cycling has many aspects that appear random. Whether or not a pattern of frequency can be detected is as yet unknown. Conditions existing on the actual building in the windstream are different from those models tested in a wind tunnel, but the significance of these

differences when applied to building design has not been determined.

B. Construction Standards

At Beltsville, Maryland, in cooperation with the American Society of Agricultural Engineers, the American Standards Association, the National Safety Countil, and the National Fire Protection Association, work continues on reviewing, proposing, and acting as consultants of those engaged in preparing standards for the safe erection and use of structures.

Current work with ASAE points toward the compilation of standards on fire safety in farm building design and construction.

In cooperation with the Southern Plan Exchange Committee and the University of Arkansas, standards were developed and compiled as a slide series, with script on methods of reducing storm damage to dwellings, and for methods of building good foundations.

C. Materials and Construction Methods

1. Hyperbolic paraboloid (HP) shapes for farm structures. Laboratory test facilities installed at Beltsville, Maryland, to evaluate the deformations caused by uniformly loading HP diaphragms were used to obtain strain gage readings on both upper and lower sides of structural shells loaded with air-pressure-bags.

Tests to date indicate that these shapes offer material savings in the construction for a great variety of farm structures. The shape is adapted to the use of timber, steel, concrete, or, if economically feasible, polymer plastics.

A significant discovery in shape design consisted of definition of the technique for changing the sag-to-hump ratio by changing from a hyperbolic paraboloid to a hyperbolic ellipsoid. Another shape connecting technique was developed to integrate HP's into units with any desired number of high and low points about the periphery of the unit.

2. Plan development. At Beltsville, Maryland, the Cooperative Farm Building Plan Exchange has continued to work with the Midwest Plan Service, the Southern and the Western Regional Plan Exchange Committees on developing plans for recreational and marketing structures -- to emphasize greater service of the farm to the urban people. Working drawings were developed and made available as follows:

Plan No. 5983, "Roadside Stand." Intended for the retail sale of farm produce, this design features hinged shelf units that permit variation in the number, width and height of the display surfaces. Pole-type construction is specified.

Plan No. 5982, "Two Display Stands for Produce," shows construction details for 4 by 8 foot stands with semicircular plywood shelves. These portable stands may be easily disassembled for moving or storage.

Plan No. 5994, "Saddle Horse Barn." This pole-type structure contains four box stalls and a combination feed and tack room. Length is variable in 12 foot (one stall) units.

Research at Beltsville, Maryland, on hyperbolic paraboloids was incorporated into Plan No. 5995, "HP Picnic Shelter." Three HP units are combined to form a triangular roof about 40 feet on a side. Three treated wood posts support the structure.

Research at Beltsville, Maryland, and in the field resulted in the preparation of Plan No. 5997, "Vacation House." Two bedrooms and a small bunk-room are provided. Construction is pole-type. Light weight floor framing is independent of the walls. The insulated crawl space plenum is pressurized for the ductless distribution of warmed air through slots around the perimeter of the floor.

Plan No. 5975, "Boat Landing," was designed to house a small boat used in partially protected waters.

Plan No. 5996, "Incinerator," (originally developed by Connecticut for the incineration of dead poultry) was issued for general use.

Plan No. 5968, "Cabin," was developed in cooperation with the Portland Cement Association and issued nationally. It is a 24' x 24' concrete masonry structure, with one bedroom, bath and combined living-dining-kitchen area. An optional 12' extension provides additional sleeping space.

D. Water Supply and Wastes Disposal

1. Farmstead and rural water systems. Studies on farmstead and rural water supply system design criteria are continuing in Maryland, in cooperation with the Maryland Station, National Fire Protection Association, Johns Hopkins University, Federal Housing Administration, Washington Suburban Sanitary Commission and selected farmers.

Data on water usage in suburban Maryland residences collected cooperatively with Johns Hopkins University (FHA Residential Water Use Research Project) in October and November of 1964 were processed and analyzed. The results indicate that Hunter's Demand Curve (National Bureau of Standards, BMS Report 79) provides a good estimate of peak demand for individual homes. Peak demand was influenced more by equipment than occupancy. This is largely due to the water using appliances available to the housewife. Our study of farm homes indicated this, but on the farm system limitations fixed peak usage.

Homes in a development (English Manor) having water supplied by a public system averaged 6.6 persons (range 2-10) and averaged 322 gpd (50 gallons per person). Peak day use was about 2.3 times this or 115 gallons per person. Per capita use declines as family size increases; this relates to more efficient loading in dishwashing and laundry. The variation in demand with family size relates to age of children.

An area served by individual water systems (Columbia Hills), south of Ellicott City in Howard County, was metered and water use recorded from August 5 to October 15. Well capacity in this area was better than anticipated. The water system limited peak demand.

There was a significant difference in water consumption between Columbia Hills and English Manor homes. English Manor homes averaged 322 gpd, Columbia Hills, 225 gpd. Part of this lower usage may be due to limitations of the individual water system. However, a significant factor may be plumbing installation in the home. Hot water piping runs were extremely short in Columbia Hills, thus less water was run to waste when hot water was desired. A study on this factor was made in the 30's. The number of water use periods was nearly equal for both areas. Columbia Hills averaged nearly 1 gallon less per use period, 5.112 vs 4.09. This is in the range where hot water piping could account for a significant proportion of the difference.

A chlorine contact time study was initiated since, while chlorination is almost universally accepted by Public Health officials as the preferred means of disinfecting water, it has not given the desired results in individual water systems in many cases. There are four factors involved in these failures.

1. Variation in chlorine demand of the raw water
2. Lack of uniform chlorine dosage
3. Inadequate mixing and contact time
4. Service and maintenance (human factor)

Factor 1 is influenced by local conditions and well construction. Factors 2 and 3 are influenced by system design, and this study was undertaken to determine means of insuring adequate contact time and mixing with intermediate storage.

It is hoped to develop a mixing and contact tank having a high first trace efficiency by reducing the induced turbulence. Entrance losses are dissipated by induced turbulence and viscous shear. Open tank studies indicated that unbalanced circulation patterns may exist even at low velocities. In an effort to correct the unbalanced flow several entrance configurations were investigated that would impose radial flow. Those inlets tested having the highest first trace efficiency had low mean flow through time and were unstable in performance. Inserting an annular baffle above the inlet resulted in a helical flow pattern from

the baffle to the outlet. Reducing the radial velocity gave lower first trace efficiency but mean flow through time approached unity.

The results obtained definitely indicate, where chlorination is desired, the diffuser inlet should be used in intermediate storage tanks; velocity in the diffuser pipe should be below 1 fps; and orifice area should not exceed the pipe flow area.

Design recommendations for maximizing the fire fighting potential of individual water systems were developed in cooperation with the Advisory Committee for Rural Fire Protection, National Fire Protection Association. Three major points were made:

1. Fire fighting demand is the heaviest anticipated demand that will be placed on the system. The fire fighting potential of the system should be a major design consideration.

2. Larger farms should plan for the use of 1 1/2" hose lines.

3. The fire fighting potential of individual water systems is very limited, as compared to the capacity of a well equipped fire department. Water should be provided on the farmstead for the fire department.

Although farm numbers are declining, farm fire losses are increasing alarmingly. Fire protection should be a major consideration in planning the farmstead water system.

A portable Intermediate Storage Water System Center was constructed. The unit consists of a 4 ton, 7x12' trailer containing a 64" diameter x 6' 1000 gallon atmospheric storage tank; 1 HP shallow well jet pump, 30 gpm at 35 psi; 120 gallon hydropneumatic tank; and the necessary controls. The rear of the trailer is designed to demonstrate the fire fighting potential of a well designed individual water system.

The portable intermediate storage system has shown several advantages. It separates well yield from farmstead demand, and makes possible determination of low leakage that could not be detected otherwise. It causes the distribution system to become the limiting factor. The system is designed to demonstrate the effect of friction loss vividly.

As a result of the system being demonstrated on a farm in Maryland having a better than average well (nearly 6 gpm sustained yield, 8640 gallons per day) the farmer installed a similar water system center using a 4000 gallon tank. It corrected his previous deficiency of having a peak demand in excess of the well yield for nearly 4 hours per day.

2. Pesticide pollution of farmstead water supplies. Work on the project was initiated in early 1965 at Beltsville, Maryland and Watkinsville,

Georgia, to develop information on: means by which pesticide pollutants reach farmstead water supplies; means for preventing entry; and means for dealing with those that do enter. To date the work has consisted principally of developing a program and obtaining facilities and equipment. Arrangements for cooperation in the study have been made with the Maryland State Department of Health and with 47 farms in Maryland. A laboratory shop building has been constructed at Watkinsville for developing equipment for removing pesticide pollutants from farmstead water supplies.

3. Farm & animal wastes disposal a. ARS Laboratory and field studies are continuing in Maryland in cooperation with Maryland Station. Work this year was concerned almost exclusively with the hydroponic possibilities of lagoon effluent clarification and salvage of plant nutrients in the form of an animal feed crop. In laboratory experiments plant nutrients in lagoon effluents were reduced as follows by 5-day retention in a hydroponic system with the grasses indicated:

	% Reduction by 5-day retention*			
Nutrient	Fescue	Rye	Reed Canary	Brome
Nitrate	79.5	70	64	47.5
Phosphate	63.5	66	54	60.5

*Averages of 5 repetitions

Grass yields ranged from a calculated 4.4 to 8.5 tons/acre with an ash content of from 1.9 to 3.1%. At the upper limits of tonnage and ash this is equivalent to a removal of approximately 500 lbs. of dissolved plant nutrients and trace elements on a one month, one acre basis.

Average requirements for a hydroponic system would be 2.2 acres/100,000 gal/day effluent discharge (a high rate for a farm lagoon but a good "mean" figure for small municipal sewage disposal lagoons), which gives a 5 day detention time.

b. CSRS Early work under regional project NC-69, Farm Animal Waste Disposal, has included collection of information on properties, handling, treatment, and disposal of animal waste. This research is cooperative among 10 North Central agricultural experiment stations and ARS, USDA. Many of the stations have investigated lagoons; others have studied use of chlorine and lime to prevent development of objectionable odors; primary or secondary treatment of swine and cattle waste in an oxidation ditch or by disposal on the land surface, properties of run-off water from open feed-lots, electro-osmosis for drying poultry manure and hydroponics as a means of clarifying and utilizing the manure lagoon effluent. The use of air oxidation devices as a means of primary or secondary waste treatment follows prior findings that anaerobic organic breakdown generally proceeds too slowly and is unreliable under most practical conditions.

4. Rural community sewage disposal. A PL-480 project to reduce costs involved in treatment and disposal of sewage from small rural communities through determination and application of optimum algal-protozoal and algal-bacterial symbiotic balances was continued at the M.S. University of Baroda, Baroda, India.

In a comparison between the activated sludge treatment and algal treatment for purification of domestic sewage, the chief advantage of algal treatment appeared to be that a good portion of both nitrogenous and phosphorous containing nutrients were taken away from the effluent for the synthesis of algal cells; in the case of the activated sludge process, a good amount of ammoniacal nitrogen was only converted into nitrites.

The effect of algal treatment on industrial wastes of Baroda, compared with activated sludge treatment, is indicated in the tabulation:

	Activated sludge effluent (6 hours)	Algal treatment (7-15 days)
BOD Reduction (%)	82.3	95.6
Am-N Reduction (%)	63.0	91.7
PO_4 Reduction (%)	64.7	78.7

The greatest reduction in BOD, AM-N and soluble phosphates is seen 15 days after algal treatment compared to six hours treatment by the activated sludge process. It may be argued that in algal treatment; the duration of treatment is considerably longer than in the case of the activated sludge process, but the capital and recurring costs will be considerably cheaper in the tropics where the sufficient sunlight for photosynthetic oxygenation is available and at no cost.

Final effluents from activated sludge treatment of sewage and industrial wastes treated with algae for further improvement in quality (tertiary treatment) showed that the inorganic nutrient substances like ammoniacal nitrogen, nitrites, nitrates, and phosphates can be removed from the effluents from secondary treatment plants, like the activated sludge process and the trickling filter, by means of algal treatment. So, algae can play a very important role in purification of not only raw sewage but also effluents from primary and secondary treatment plants.

A study of the conventional type of oxidation pond, using a laboratory model, showed results as in the tabulation: (Ordinarily a pond takes 20-30 days before it starts to function. This period can be roughly divided into two stages called the bacterial phase and the algal phase).

	Raw sewage mg/2	Reduction during bacterial phases %	Reduction during algal phase %	Overall reduction %
Dissolved oxygen	0	0	0	0
BOD	36.1	81.2	54.0	91.7
Am-N	37.6	53.2	15.3	60.4
PO_4	26.0	21.5	35.8	50.0

The reductions in BOD and ammoniacal nitrogen are greater during the bacterial phase than during the algal phase. Another noteworthy feature was that though the pond was greenish, there was no measureable quantity of dissolved oxygen, and yet there was good reduction in BOD. This has to be attributed to photosynthetic oxygen production in the water and it is being immediately used up for BOD satisfaction, leaving little in the liquid medium.

A modified high-rate oxidation pond studied under laboratory conditions showed that in 36 days exposure to light at about 25°C, there was a reduction of nearly 98% in BOD, 99% in ammoniacal nitrogen, and nearly 93% in soluble phosphates. The high increase in phosphate reduction is due to high pH attained as a result of intense photosynthesis.

E. Farmstead planning

1. Farmstead model layout studies. Studies on the use of models for analyzing farmstead layout problems neared completion in cooperation with the Minnesota Experiment Station at St. Paul, Minnesota. These studies have demonstrated that scale models can prove valuable aids in farmstead planning, analyzing materials flow problems, eliminating safety hazards, analyzing alternate arrangements, and planning for orderly expansion of the enterprise. They also showed that the scale models are only one step in the orderly process of planning the farmstead ant that some system of numerical analysis is needed to supplement their use.

2. Chore time standards. Studies on time standards for performing farmstead work elements are continuing in cooperation with the Minnesota Station, at St. Paul, Minnesota.

A study of free-stall slat-floor housing for dairy cattle is being conducted in pilot units of cold and warm housing with outside feeding. The objectives are to determine the design criteria for free stalls, economical methods of manure handling, and recommendations for feed lot design. As a result of the first full winter's operation of the study it was found that the animals do not spend enough time in either type during the daylight hours, even in sub-zero weather, to keep the manure under the slats from freezing. However, the manure in the warm unit can be kept unfrozen later in the fall than the manure in the open unit, when the temperature goes below freezing at night but rises a few degrees above freezing for about four hours in the afternoon.

A study of the use of separate animal-operated self-closing entrance and exit doors in the closed unit has shown that it requires about two to four days to train all of the animals to use them properly. It was found however, that for best operation by the animals it was necessary to provide plexiglass panels in the doors such that the animals can see what is on the other side before they attempt to push the doors open.

In the study of feed-yard layout design, time lapse photography is being studied as to its suitability for recording animal movements in the yard area. Thus far it has been determined that is is necessary to use roll film of two different emulsion speeds if a record is to be obtained over the full period of dawn to dusk. Time intervals of 4 and 7 seconds appear to be the best time lapse between frames to record the animal movements.

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No reportable progress during reporting period.

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AREA NO. 11: ELECTROMAGNETIC AND ULTRASONIC ENERGY FOR INSECT CONTROL AND OTHER FARM USES

Problem. Electromagnetic radiation has many established farm uses but research indicates many other highly useful potential capabilities in farm production, such as killing insects harmful to stored grain without leaving residues. Annual losses in recent years due to insects in field crops stored on the farm approximate 200 million dollars. To minimize the use of possibly hazardous chemicals and their residues in food products as much as possible, there is need for widespread investigation of non-chemical pest control methods, such as study of insect response to all possible types of radiation and sound and exploitation of weak physical links in the life of particular insects. There is need for development of better electric insect survey traps to sample insects in flight, and to permit control programs to be timed with greater accuracy. Since there is zero tolerance of DDT in milk, there is need for an electrical or physical means of controlling flies in and around dairy barns and milk houses. There is need for detecting or removing insects in food processing plants, including fruit flies in tomato canning plants, and larvae of the cabbage looper and imported cabbage worm that may be clinging to spinach leaves when delivered to the processing plant. The promising results of a project to control tobacco hornworm with only three traps per square mile using ultraviolet radiation as the attractant in a newly designed blacklight insect trap has raised the question, "What other insects can be controlled by electrical methods and equipment alone or in combination with insecticides, chemosterilants, and biological attractants?" Production of many crops is hampered by poor, slow, or non-uniform emergence of seedlings after the seed is planted. Some electrical treatments have been found to accelerate germination and seedling emergence. If emergence in the field can be speeded up and better uniformity obtained, weed control can be much more effective, with resulting increased efficiency in production of crops. Treatments also increase the percentage of germination for some seeds and would therefore enable the establishment of good stands with lower investments for seed. Further, uniform emergence tends toward more uniform saturation with increased practicability of once-over harvest programs.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied research involving agricultural and electrical engineers and physicists working cooperatively with USDA entomologists and with the Experiment Stations of eleven States. Electrical and physical methods for corn borer control are studied in Iowa, cotton insect control in South Carolina and Texas, with the Texas project contributing to Regional Research Project S-37, Basic Factors Involved in Control of the Pink Bollworm. Electrical and physical methods of tobacco insect control are studied in North Carolina, South Carolina, Kentucky, and Virginia, and vegetable insect control and light trap

design in California and Indiana, with financial assistance from the Indiana Electric Association through the Purdue University Experiment Station. Fly control in dairy barns is studied at Beltsville, Maryland. Research on electromagnetic energy for control of insects in stored grains and seeds is carried on in Nebraska and for conditioning seed to improve germination and emergence in Nebraska, Tennessee, and Washington.

Studies relating to potential use of radiofrequency (RF) energy for insect control and improvement of seed germination are in cooperation with the Departments of Agricultural Engineering, Entomology, and Agronomy at the Nebraska Agricultural Experiment Station. Cooperative help on some phases of studies was furnished by the Crops Research Division, ARS, the Asgrow Seed Company, the Agricultural Engineering Departments of the University of Idaho and Texas A & M University, and others.

Studies on effects of electric glow-discharge radiation on seeds and plant products have been continued at Knoxville, Tennessee, in cooperation with the Departments of Agricultural Engineering, Agronomy, and Nutrition of the Tennessee Agricultural Experiment Station and the Crops Research Division, ARS. At Pullman, Washington, effects of glow-discharge radiation on germination of seeds and early plant growth were studied in cooperation with the Washington Agricultural Experiment Station, Washington State University.

The Federal scientific effort devoted to Agricultural Engineering research in this area totals 11.3 scientific man-years; of this number 5.8 are devoted to electric traps for insect survey, destruction and control; 0.8 to components and design of electric insect traps for survey and control; 1.0 to physical methods of fly control; 1.0 to sonic and ultrasonic energy for insect control; 2.0 to radiofrequency treatment of grain and forage seed; and 0.7 to program leadership.

A 4-year contract is in effect with VPI to investigate the possibility of attracting or repelling flies with sound.

PROGRAM OF STATE EXPERIMENT STATIONS

Several of the States are engaged in programs of basic and applied research on the possible use of some of the various forms of electrical and physical energies as a means for improvement of the potential capabilities in farm production.

Investigations in progress, many of which are cooperative with the Department, involved the evaluation of the use of radiofrequency energy for treatment of grains to destroy insect infestation and treatment of seeds to improve their germination characteristics; exploration of the feasibility of using ultrasonics and electric shock to control rats, mice, and birds; studies of the possibilities for a major advancement in the technology of small particle depositions through the application of

electrostatic, thermal or other inertial forces; and use of light sources of various wavelengths for attracting and collecting insects which infest many of our economic crops.

A total of 1.5 scientist man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Electric Traps for Insect Survey, Destruction and Control

1. Electric Traps for Vegetable Insects

Research on use of electric light traps for control of vegetable insects was conducted principally at Lafayette, Indiana, and Riverside, California.

At Lafayette, Indiana, research on the development of equipment for attracting and destroying insects with electric energy was continued in cooperation with the Departments of Agricultural Engineering and Entomology of the Purdue University Agricultural Experiment Station. The work was supported in part by the Indiana Electric Association. Migration and occurrence of corn earworm moths and the occurrence of several other insect species of economic importance were studied in cooperation with personnel of the Purdue Department of Entomology as a part of Regional Project NC-67, Migration of Aphids and Noctuids. Field experiments were expanded and continued for the eighth consecutive season to investigate the effectiveness of electric insect traps for controlling insect damage in tomato production. Species whose damage to tomatoes might be reduced through use of light traps include the tobacco hornworm, Manduca sexta (Johannson), tomato hornworm, Manduca quinquemaculata (Haworth), tomato fruitworm or corn earworm, Heliothis zea (Boddie), various cutworms, and drosophila. Effectiveness of control was studied relative to distance and direction of plants from two light traps in the field plot. The traps were equipped with five 15-watt fluorescent blacklight lamps and a fan mounted between the trap funnel and collection container. Light traps were the only insect control measure used to protect the tomatoes. Damage in the field with light traps was compared to a similar planting without light traps about 2,000 feet away.

Insect-infested plants, ripe fruit damage, and trap catches were used as indicators of the effectiveness of light traps in controlling insect damage to tomatoes. As in 1964, hornworm infestation near the traps was substantially reduced. Hornworm infestation in the field equipped with traps was delayed about 6 weeks, as compared to the planting without traps. No tomato varietal differences were noted in degree of hornworm control. Maximum distance of plants from a light trap in the field protected with light traps was 532 feet. Hornworm damage in this field was generally lower than that observed in the unprotected field. On August 10, 12 percent of the plants in the light-trap field were infested compared to 54 percent in the unprotected planting. On September 7, 57 percent of the

plants in the light-trap field were infested compared to 99 percent in the unprotected field.

No drosophila infestation occurred in either field, and tomato fruitworm damage was negligible. Damage to fruit caused by insects other than hornworms, primarily cutworms, was uniform throughout both fields. No appreciable control for cutworms was effected either in 1964 or 1965.

Results of experiments over the past few years indicate that hornworm and tomato fruitworm damage to tomatoes can be substantially reduced by the use of blacklight insect traps. No differences in infestation were noted due to differences in direction of the plants from the traps. Because of protection which light traps have provided cucumbers from cucumber beetles in past work, further experiments are planned to study the possibility of using an integrated insecticide and light-trap program to control these insect pests in 15- and 32-acre, commercial-sized plantings. Objectives of the new experiments are twofold: (1) To perform a basic scientific study in a commercial planting to confirm or deny earlier experimental results in small plots, and (2) to demonstrate the use of insect traps to potential users.

At Riverside, California, work was conducted in cooperation with the University of California and the Entomology Research Division (ENT), ARS on a new project to study methods of utilizing electric energy in controlling vegetable insects. Blacklight insect traps were installed near Riverside, and tests were run to determine their effectiveness in attracting cabbage loopers, Trichoplusia ni (Hübner). Light traps with virgin females confined in cages on the traps caught up to 40 times more male cabbage loopers than traps with no females. On the average, 10 times more males were caught in traps with virgin females than in traps without them. Location of virgin females within 40 feet of light traps effected increased light trap catches of male cabbage loopers. Effectiveness of the same confined female moths in increasing light trap catches continued for at least 2 weeks without decline. The number of moths caught in the traps was not affected by confined male cabbage loopers at the traps or by virgin females when dispersal of the female sex pheromone was prevented. A trap equipped with virgin females as the only attractant caught approximately the same number of males as traps equipped with a blacklight lamp as the only attractant. Studies involving the release of 17,000 marked laboratory-reared moths showed that 8.4 percent of these moths were recovered in traps in the release area. A few moths were captured 10,000 feet from the release point; however, 93 to 100 percent of those captured were caught within 1 mile of the release point. Based on promising results of this year's data, a large field-trapping installation will be installed in Arizona in an attempt to reduce cabbage looper infestation. In an effort to apply chemosterilants to insects, light traps were modified to permit captured moths to escape after contacting the chemosterilant. The method worked well in the laboratory, but was not successful in the field because small insects, dust, and high temperatures adversely affected the chemosterilant-treated surfaces. Preliminary investigations were conducted at Charleston, South Carolina, to

determine potential usefulness of light traps in work with the southern potato wireworm, Conoderus falli Lane. Work there will be continued on about the same basis with AE participation limited to advising ENT personnel on the use of electric traps.

2. Electric Traps for Grain Insects

Light traps are useful in studies of the European corn borer and in control work for determining the time of emergence, the dates of maximum flight activity, the comparative activity from year to year, and the timing of insecticide applications. Light traps have been operated near Ames, Iowa, since 1952 in cooperation with the USDA European Corn Borer Investigations Laboratory and the Iowa Agricultural and Home Economics Experiment Station. Trap collections of the European corn borer were much lower in 1965 than in 1964, indicating the general reduction in infestations as compared to the previous year. The traps will be operated in 1966 with the same cooperators.

3. Electric Traps for Cotton Insects

Research on the use of visible and near ultraviolet radiant energy for attracting and collecting various species of cotton insects was conducted principally at College Station, Texas, with limited studies also conducted at the Boll Weevil Research Laboratory, State College, Mississippi. Studies in Texas were cooperative with the Texas Agricultural Experiment Station and ENT, ARS, College Station, Texas. The Physics Department, Texas A & M University, cooperated on an informal basis in certain phases of the studies. This project contributes to Regional Project S-37, Basic Factors Involved in the Control of the Pink Bollworm. In laboratory studies to determine the spectral response of adults of the cotton bollworm, Heliothis zea (Boddie), and the tobacco budworm, Heliothis virescens (Fabricius), test equipment and techniques have been developed to use the group response method. In cooperative work with biophysicists of the Physics Department, electroretinogram (ERG) studies were conducted with adults of the cotton bollworm and tobacco budworm. Spectral sensitivity curves obtained with these techniques were almost identical for these two species in the 380- to 650-nanometer (nm) wavelength range. Peak response for both species was obtained in the blue-green region at about 515 nm. ERG results indicate considerable promise for use of this technique in predicting phototactic responses of insects to radiant energy. Results of these studies will provide a basis for specifying design parameters for efficient attractant lamps for the bollworm and tobacco budworm. Further ERG studies are planned at shorter and longer wavelengths.

Cooperative activities with the Department of Entomology, Texas A & M University, involved modifications of irradiation equipment and calibration of a detection system used in studies to determine the diapause action spectrum of the pink bollworm.

In cooperation with a special Heliothis committee of the Entomology Research Division, ARS, observations were made in Reeves County, Texas, of the large-scale use of electric insect traps. About 16,000 acres of the 46,000 cotton acreage of Reeves County was involved in an insect control program during 1965 that used electric insect traps as an aid in the control of Lepidoptera species, principally the cotton bollworm and the tobacco budworm. About 2,000 traps, consisting of six different basic designs, were installed by farmers within a 12- by 35-mile north-south belt through the irrigated cotton farming area. Valuable engineering information was obtained on trap design features and installation and operational problems. Entomological observations were also obtained concerning the effectiveness of the traps in reducing bollworm populations. From an engineering standpoint, the major problem involved in such large-scale use of electric insect traps was power distribution. Damage of field power distribution cables caused frequent power interruptions both with buried and above-ground systems.

Further studies on the use of electric insect traps as a means of reducing bollworm populations will be conducted during 1966 at Guemez, Mexico, in cooperation with the Southwestern Cotton Insects Investigations, ENT, Brownsville, Texas. Traps have been installed at a density of about 1.25 traps per acre within a somewhat isolated area planted to corn and citrus.

In very limited work this year at State College, Mississippi, a test chamber constructed of glass has been built for studying spectral response of the boll weevil. Work will continue on a limited scale to evaluate the new equipment for studies of insect response to light. Some studies of light quality and photoperiod on the induction of diapause in the boll weevil are also underway at the Boll Weevil Research Laboratory.

4. Electric Traps for Tobacco Insects

Research on development and use of electric insect light traps for attracting and controlling tobacco insects was continued at Blacksburg, Virginia, in cooperation with the Virginia Agricultural Experiment Station; at Oxford, North Carolina, in cooperation with ENT, ARS, and the North Carolina Experiment Station; and at Lexington, Kentucky, in cooperation with the Kentucky Agricultural Experiment Station. Limited investigations were initiated in cooperation with the Entomology Research Division at Quincy, Florida, and on St. Croix, Virgin Islands. On St. Croix, trapping equipment was installed for use in area population control studies to begin in 1966. A 2-1/2-year contract was awarded to Clemson University to provide engineering evaluation of an area population control study in South Carolina and to conduct research on trap development.

At Blacksburg, Virginia, electrophysiological studies of the visual sensitivity of tobacco hornworm moths have indicated two sensitivity peaks, a minor peak in the ultraviolet spectrum at approximately 370 nm, and a major peak in the visible spectrum at 550 nm. Visual sensitivity of male moths has been two to three times greater than that of female moths for

corresponding wavelengths and intensities. Optical and electrical instruments have been assembled and calibrated to provide estimates of the absolute values of electromagnetic energy incident upon the moths at various wavelengths in these studies. In field experiments at Chatham and Blacksburg, Virginia, light traps equipped with fans below the lamp did not catch more hornworm moths than traps without fans. Increased numbers of corn earworm moths and cabbage looper moths were captured in the traps equipped with fans. A similar trend was indicated in the capture of armyworm moths, Pseudaletia unipuncta (Haworth). In similar tests conducted around fields of shade-grown tobacco at Quincy, Florida, traps with fans did not appear to be any more effective in catching corn earworm, tobacco budworm, or hornworm moths than were traps without fans. In both Virginia and Florida, light trap catches were increased by increasing the number of 15-watt lamps from one to four per trap or by changing from a 15-watt to a 30-watt lamp, but the increased catches were less than directly proportional to the increased lamp wattage.

At all three locations, late-season tests with a newly developed trap, which automatically segregates catches according to the time of night when insects are captured, showed that several economic insect species were active throughout the night. At Quincy, Florida, the time-of-night catch data are being correlated with microweather data obtained by a meterological research unit. Also, at Quincy, Florida, entomological observations in cooperation with a shade-tobacco farmer revealed significant reduction of insect damage attributed to use of electric insect traps around the field. Only two applications of insecticide were required in the shade equipped with traps as compared to 17 insecticide applications on a similar shade not equipped with traps which was used for comparison.

On St. Croix, a group of traps across the long dimension of the island was operated to determine what positively phototactic insect species were present on the island and to obtain data on the population magnitude. Fan-type electric insect traps have now been installed over the entire 84-square-mile island area. Area control studies will begin on St. Croix in 1966. The area will be used by ENT and AE as an isolated field laboratory for testing effectiveness of electric traps integrated with other insect control measures.

At Oxford, North Carolina, field investigations on the use of insect light traps covering a large area to control tobacco insects were continued in cooperation with ENT, ARS. A circular area 20 miles in diameter (314 square miles) is covered with 1,116 traps. Sampling traps on the four principal radii extending from the area and one-half acre nontreated tobacco plots were added at about 2-mile intervals between 20 and 30 miles from the center of the area to extend sampling further into untreated areas. Preliminary analysis of the 1965 data indicates trends similar to those of 1963 and 1964 when substantial reduction of hornworm population was achieved. Tobacco insect populations were low throughout North Carolina during 1965, and damage to tobacco was below the economic level both inside and outside the test area. Estimated reductions in hornworm population at the center of the test area as compared to points 12 miles from the center were 87 and 50

percent, respectively, for males and females. Compared to points 30 miles from the center, corresponding estimated reductions were 92 and 65 percent. The numbers of hornworm eggs and first instar larvae on tobacco which was not treated with insecticides were significantly less at the center of the area than at 30 miles from the center. Numbers of hornworms parasitized by Apanteles congregatus were 77 percent less at points 30 miles from the center than at the center of the test area. Light trap catches of tobacco budworm and corn earworm moths were higher at the center of the area than at 30 miles from the center, perhaps because of a higher density of tobacco and corn crops near the center of the area. The average number of insecticide applications on tobacco outside the test area was greater than that applied inside the area.

In tests comparing traps equipped with fans and traps with additional lamps to traps with a single lamp and no fan, traps with fans generally caught more total insects, but differences were not significant. Using additional lamps in traps increased catches significantly, but not in direct proportion to the increase in lamp wattage. Traps equipped with new lamps caught significantly more tobacco hornworm moths than similar traps equipped with lamps which had been used for 10 months previously. Experiments with light traps equipped to separate nightly moth catches into hourly intervals revealed that the greatest capture of tobacco insects occurred between 10 p.m. and 12 p.m. EST.

Research on developing and evaluating effectiveness of electric insect traps installed on a community-wide basis with farmer participation was continued at Lexington, Kentucky, in cooperation with the Kentucky Agricultural Experiment Station. The center of the test area in Kentucky is located about 3-1/2 miles north of Shelbyville. The number of light traps in the 12-mile-diameter circular area (113 square miles) was increased from 224 to 312 this year. Check traps are located on principal radii at intervals of 1 mile inside the area and at 2-mile intervals outside the area. Forty-eight 1/2-acre plots of tobacco were selected on radii at 45 degrees to the radii on which check traps were located. Half of these plots are within the test area, and the other half are outside of the test area. No insecticides were applied to these plots. The peak moth catches inside the area occurred during the week of August 16, while peak catches outside the area were obtained during the weeks of July 26 and August 16. Catches of the tobacco hornworm moth were much greater in July than in any other month. A somewhat higher percentage of male hornworm moths was caught outside the test area than inside the area, respectively, 71.6 percent and 62.7 percent for the season. These figures may reflect some effect on the male population attributable to the high density of light traps in the test area. Egg and larval counts on tobacco plants in the 1/2-acre fields were low throughout the season, but were highest during late July and August. Substantially more moths were caught per trap outside of the test area than inside the area, and egg and larval counts in the field plots indicated higher population levels outside the test area than inside.

Large area control studies and trap evaluation investigations will be continued both at Oxford, North Carolina, and Lexington, Kentucky. Through

contract with Clemson University, similar observations will be obtained in South Carolina. Work at Oxford will include trap efficiency and insect catching range studies, and weather variables will be studied as they relate to insect activity and light trap catches.

5. Electric Traps for Turf Insects

Cooperative studies with Purdue University were conducted at Lafayette, Indiana, to investigate the use of electric light traps for controlling the larger sod webworm, Crambus trisectus (Walker), in lawns. Traps were used both to indicate the seasonal abundance and for control purposes with promising results. Trap records from the past two years indicate that the larger sod webworm comprises 68 percent of the webworm population in areas sampled at Lafayette, and that about 70 percent of the webworm moths captured were females, which still carried eggs. Very few larvae or pupae were found within 75 feet of single-lamp blacklight traps used in the experimental installations. These studies will be continued using traps installed in the same lawns which were used in 1965. Blacklight survey traps have been used extensively during the past several years by PPC in detection and quarantine work with the European chafer. Use of traps for European chafer surveys was expanded this year, and additional areas of infestation were discovered in northwest Pennsylvania and northeast Ohio. Preliminary tests of electric traps as a possible control measure for the European chafer were begun in New York this year in cooperation with ENT, ARS.

6. Electric Traps for Fruit and Nut Insects

In cooperation with ENT, ARS, preliminary investigations were conducted at Yakima, Washington, on the codling moth, Carpocapsa pomonella (Linnaeus). Potential usefulness of light traps for control of this insect has been indicated in several earlier studies, and work at Yakima will be expanded to further explore possibilities of light traps for codling moth control. Preliminary experiments were also conducted at Albany, Georgia, to explore possibilities of using light traps for pecan insect control. Results were encouraging, and experiments using light trap installations for pecan insect control will be studied further in 1966.

B. Components and Design of Electric Insect Traps for Survey and Control

At Lafayette, Indiana, tests were made to study the response of the tobacco budworm moth to various commercially available lamps under controlled environmental conditions in a free-flight, light-response laboratory. The insects were inactive at temperatures below 65° F. but were active at temperatures of 70° F. or higher. In tests with various lamps using an environmental temperature of 77° F., the blacklight (BL) and the blacklight filtered (BLB) fluorescent lamps were much more effective in attracting the insects than yellow, daylight, or green lamps of the same wattage rating. The percentage of insects attracted by the BL lamp was more than twice that attracted to the BLB lamp.

In field studies, light traps equipped with a fan and five 15-watt BL lamps caught about twice as many corn earworm moths as the gravity-type survey traps with one 15-watt BL lamp as the attractant. Males and females were caught in equal numbers. Using traps equipped with a device to separate the catch for different time intervals during the night, field studies were conducted on the nocturnal activity of the corn earworm, tobacco hornworm, tomato hornworm, and variegated cutworm, Peridroma saucia (Hübner), and the yellow-striped armyworm, Prodenia ornithogelli Guenee. Catches of corn earworm moths through the night were nearly uniform from an hour after sunset until an hour before sunrise. Tomato hornworm moths were captured primarily in the early morning hours, while tobacco hornworm moths were captured at equal rates from sunset until an hour before sunrise. The male-to-female sex ratio for tobacco hornworm moths was 4:1 and 3:2 for tomato hornworm moths. The corresponding sex ratio for the variegated cutworm was 3:2, and these moths were captured uniformly from sunset until an hour before sunrise. Sex ratio for the yellow-striped armyworm was 2:1. These moths were captured in greatest numbers during the early morning hours.

Cooperative studies with ENT were continued at College Station, Texas, on design improvements for a boll weevil survey trap. Liquids, sticky materials, and electric grids were equally effective for killing weevils attracted to a trap designed for use of a 12- by 12-inch strontium-blue fluorescent panel lamp. Electric grids appear preferable because of ease of insect removal for identification. Operation of the experimental trap in a 4- by 4-foot screened cage indicated a trapping efficiency for boll weevils of approximately 70 percent. Further cage and field studies will be conducted with experimental trap designs during 1966.

Trap comparison tests revealed no conclusive information on the relative merits of various trap designs for general purpose insect collection. Trap mounting height influenced catches on a specific basis, trap heights above 6 feet being more effective for large moths and least effective for smaller moths, particularly the cotton bollworm. Test data also showed that a fivefold increase in numbers of traps at one location with 10-foot spacings between traps produced a fourfold increase in the catch of bollworm moths.

Kerosene filled pans located on the ground surface showed promise as a technique for measuring blacklight survey trap efficiency. The data indicate the survey trap may be collecting less than 60 percent of the moths attracted to its vicinity. Further studies of trap efficiencies will be conducted using this surface pan technique in order to develop information needed for trap design improvement.

Cooperative activities concerning the use of electric insect traps for insect survey and detection in the North Central and several Northeastern States were continued. Survey entomologists in an area including nine North Central States continued to use light traps for survey reports on insects of economic importance. The use of traps by PPC, ARS, for European chafer surveys was also expanded, and additional areas of infestation were discovered

in northwest Pennsylvania and northeast Ohio. Use of electric traps by PPC for general population and detection surveys was increased, particularly at ports along the St. Lawrence seaway.

Participation in activities under North Central Regional Project No. 67, Migration of Aphids and Noctuids, again proved effective in expanding the use of blacklight traps for survey. The purpose of this project is to determine the causes, the pathway, and the time of aphid and corn earworm migrations. Data on presence and abundance of several species of insects of economic importance were determined and reported from the 19 traps used in the NC-67 survey system throughout Indiana. Collections provided valuable information to extension workers and farmers as to the need for and time to apply chemical controls.

C. Physical Methods for Fly Control

Investigations of physical methods for controlling flies in dairy operations were continued at Beltsville, Maryland, as a cooperative effort of Entomology, Animal Husbandry, and Agricultural Engineering Research Divisions, ARS, but under a handicap from shortage of personnel.

A study was initiated to evaluate the effectiveness of farmstead sanitation practices in reducing fly populations and to determine whether efforts by individual farmers are beneficial, or whether concerted community action is essential. Monitoring surveys were made of native fly populations on neighboring farmstead areas and of the dispersal of marked flies released at various points within the area.

Removal of fly-attractive materials from a dairy complex appeared to reduce the house fly population by about one-third. Stable flies were not much affected by barn and corral cleanup. House flies dispersed more rapidly from areas with few breeding sites than from areas with many breeding sites and were more attracted to farms with uncleaned corrals and barns than to farms having daily manure cleanup. Most house fly dispersal occurred within 4 days after adult emergence and was quite rapid to farms within a 1-mile radius of the emergence site.

A companion study was initiated by AH through contract with Louisiana State University to evaluate effects of sanitation under the favorable conditions for flies prevailing in the South and to compare the benefits derived from different levels of effort to maintain sanitation on typical farmsteads. Cooperators have been selected and detailed observations will be made during the 1966 and 1967 seasons.

D. Sonic and Ultrasonic Energy for Insect Control

During 1965, AE initiated active participation with ENT on a project at Florence, South Carolina, to explore possibilities of ultrasonic energy in controlling cotton insects. These studies are cooperative with the Clemson

University Pee Dee Experiment Station. Work on the use of sonic energy to attract or repel flies was continued under contract with the Departments of Agricultural Engineering and Entomology, Virginia Polytechnic Institute, Blacksburg, Virginia.

At Florence, South Carolina, major AE activity involved familiarization with the research program and literature review, calibration of ultrasonic equipment, and supervision of the construction of a new laboratory building. A calibration chamber was designed and constructed for calibration of ultrasonic speakers, and several speakers with good output from 10 to 100 kilohertz (KHz) (kilocycles per second) were calibrated. Three field tests were conducted using ultrasound at frequencies of 21 to 22 KHz to explore possibilities of controlling the cotton bollworm and tobacco budworm. No effective control was achieved in these tests, but moths were observed to respond to individual ultrasonic pulses. These studies will be continued on the same basis in 1966, and some additional experiments will be conducted on the influence of ultrasound on moths attracted to light sources in efforts to determine the characteristics of effective ultrasonic radiations for repelling these moths.

At Blacksburg, Virginia, house flies and face flies have been exposed to sounds of frequencies ranging between 100 Hz and 100 KHz at three different intensity levels.. Tests included both steady and pulsating tones. Pupae of the face fly have also been exposed to sound energy at frequencies between 100 Hz and 5 KHz. Conclusive results are not yet available in these studies. Work for next year will include tests with both house flies and face flies in accordance with suitable statistical designs which are being developed for the experiments. Techniques for testing and handling flies will be refined, and studies of sonic frequencies generated by flies in flight will be initiated.

E. Radiofrequency and Glow-discharge Energy for Insect Control and Treatment of Seed and Plant and Animal Products

Studies concerning potential use of radiofrequency (RF) energy for insect control and improvement of seed germination have been continued. Investigations were directed toward developing basic information and evaluating possible agricultural applications. The research is cooperative with the Departments of Agricultural Engineering and Entomology at the Nebraska Agricultural Experiment Station. Cooperation has also been provided by Crops Research Division, ARS, the Asgrow Seed Company, the Agricultural Engineering Departments of the University of Idaho and Texas A & M University, and others.

Studies of the effects of glow-discharge radiation on seeds and plant products have been continued at Knoxville, Tennessee, in cooperation with the Crops Research Division, ARS, and the Tennessee Agricultural Experiment Station. At Pullman, Washington, studies of effects of glow-discharge

radiation on germination of seeds and on Salmonella in dried egg powder were continued in cooperation with the Washington Agricultural Experiment Station.

1. Grain and Forage Seed Treatment and Insect Control Studies

Previous studies have shown that all developmental stages of all stored-grain insects studied can be killed by exposure for a few seconds to RF fields of sufficient intensity, which do not damage wheat for germination or milling and baking purposes. On a practical scale, the electrical treatment would be more expensive than chemical insecticide controls.

Efforts to improve the efficiency of the method by applying the energy in high-intensity pulses were successful for one species but did not increase mortality of stored-grain insects generally for energy input comparable to unmodulated operation. A new pulse modulator has been designed and partially constructed to provide shorter pulses which may be more effective in providing control of the insects infesting grain.

In physiological studies, RF treatment of larvae of the yellow mealworm, Tenebrio molitor (L.), resulted in increased weight loss and oxygen consumption in the treated insects as compared to the untreated. Increased protein synthesis and catabolism of amino acids were also noted, and these disturbances did not appear to be completely explained by heating effects alone.

The relative dielectric properties of grain and insects influence the amoun of energy each absorbs from the RF electric field. Since the dielectric properties are frequency-dependent, knowledge of these properties over a wide frequency range would be helpful in determining optimum frequency ranges for insect control purposes. Development of a method for determinir these properties in the 50- to 250-MHz range is nearly completed and will provide data to supplement that already available for insects and grain in the 1- to 50-MHz range.

Earlier experiments have shown that RF electrical treatments are effective in reducing the percentage of hard seed and correspondingly increasing normal germination in alfalfa, red clover, ladino clover, and to a lesser degree, in sweetclover. Quality of RF-treated seed samples continued to hold up as well as untreated seed after 5 years in uncontrolled storage. RF treatment for hard-seed reduction was studied on 27 different alfalfa seed lots from Utah, Nevada, Oregon, and Idaho, which were selected for high hard-seed content. On the average, hard-seed percentage was reduced from 36 percent in the untreated samples to 12 percent by the RF electrical treatment. Infrared treatments for hard-seed reduction were also obtained on all of these seed lots for comparison, and infrared treatments were equally effective in lowering hard-seed content. In additional studies with sweetclover seed, neither one nor two additional RF treatments produced further hard-seed reduction on samples which did not respond effectively to the initial RF treatment to lower hard-seed content.

Limited work with several varieties of seed corn showed that germination and early growth of some varieties were accelerated. Results were evaluated by daily measurements of radicle and plumule development.

At Pullman, Washington, sweetclover seed samples at 11 different moisture contents between 1.63 and 8.15 percent were irradiated in the glow discharge at 12 different treatment levels to further define relationships between seed moisture content and reduction of hard-seed percentage achieved by electrical treatment. Some reduction in hard-seed content was obtained at moisture levels of 5 to 6 percent. As the moisture content was reduced, a greater reduction of hard-seed content was achieved over a wider range of treatment levels. At moisture contents above 6 percent, any reduction in hard seed was accompanied by an equivalent increase in the number of dead seeds.

Experiments to determine the morphological effects of glow-discharge radiation on alfalfa seeds were conducted in cooperation with the Department of Agronomy, Washington State University. Histological methods were not successful because satisfactory sectioning of mature seeds was not practical. The use of the X-ray contrast method to follow the entry of radio-opaque dyes into the seed indicated that, in the majority of cases, the dye was absorbed through the hilum area of the seed.

Studies will be continued to evaluate effectiveness of RF energy for improving germination and emergence of different types of seeds.

2. Vegetable and Ornamental Seed Studies

In the previous 3 years, RF treatment of spinach seed has provided an acceleration of germination and emergence from soil in some tests. This year, in cooperation with Dulany Foods, of Fruitland, Maryland, two varieties of spinach seed were treated with RF energy and returned to Maryland for field testing. Laboratory tests of germination conducted by Asgrow Seed Company revealed acceleration of germination for both varieties; however, early emergence in field tests was improved for only one variety.

In preliminary experiments with RF electrical treatment of seed of some ornamentals, increased germination due to treatment was obtained for some low-germinating lots of cosmos, ipomea, and Bells of Ireland.

In other preliminary work cooperative with CR, ARS, personnel at Texas A & M University, germination of mesquite seed was improved by RF treatment, but these treatments failed to increase germination of yaupon, huisache, and McCartney rose seed.

Additional experiments are planned to study the effectiveness of different combinations of variables in reducing hard-seed content and in improving the germination of horticultural crop seed.

3. Cotton and Cottonseed Studies

Limited studies were continued on RF and glow-discharge treatment of cottonseed in cooperation with Texas A & M University and our field station at Knoxville, Tennessee. Flood damage to field plots reduced the value of field data obtained this year, and earlier results on improved emergence and yield were not confirmed. In other experiments, glow-discharge and RF treatments increased field emergence of an experimental hard-seeded lot of cottonseed.

Results of field tests conducted at the University of Tennessee Milan field station showed that Empire cottonseed treated in a 17.5-KHz glow discharge at a pressure of 3 mm Hg for 5 minutes germinated earlier than untreated seed and produced a stand count of 90 percent before thinning as compared to 79 percent for the untreated seed. The test will be repeated in 1966. Work was conducted on glow-discharge treatment of cottonseed lots normally containing high percentages of hard seed. Radiofrequency electrical treatments were also provided for the cottonseed at the Lincoln, Nebraska field station. Both provided increases in germination, though the degree of improvement produced by each type of treatment in different tests was not consistent. Seed received for 1966 experiments did not contain the high hard-seed percentage desired, but laboratory tests involving both RF and glow-discharge treatments will be conducted. In an effort to eliminate weak seeds using glow-discharge treatment, Empire cottonseed was treated at high current levels and planted in the field. In obtaining seed for treatment, half of the bolls of each plant were self-pollenated, and the other half were open-pollenated. In germinator tests, seed from the self-pollenated bolls withstood high-current treatments better than did seed from the open-pollenated bolls. Further field investigations will be conducted in cooperation with CR in 1966.

Limited studies were continued on glow-discharge and RF treatment of cottonseed in cooperation with Texas A & M University and our field station at Lincoln, Nebraska. Laboratory germination tests showed no improvement this year in germination or radicle development as a result of the treatments. Flood damage to field plots in Texas reduced the value of field data obtained this year, and earlier results on improved emergence and yield were not confirmed.

Cotton fiber bundles were treated in the glow-discharge chamber for cooperative investigations with CR to determine the effects of the glow-discharge treatment on the stress-strain characteristics of cotton fiber.

4. Pine Seed Studies

Samples of three pine seed varieties were exposed to RF treatments in cooperation with Forest Service personnel at Berkeley, California. In preliminary work, seeds of three different varieties were treated to learn whether germination might be encouraged without 90-day storage in cool, moist chambers. Quality of samples was poorer than anticipated, and results were not conclusive, but work will be continued on a limited scale.

5. Soybeans

Field tests in cooperation with the Department of Agronomy, University of Tennessee, to determine whether glow-discharge treatments might improve development, revealed no increase in yield as a result of glow-discharge treatments. Work on investigations of effects of glow-discharge treatment on soybean oil, which are cooperative with the Department of Food Technology, University of Tennessee, were temporarily interrupted because of transfer of AE personnel. This work is again underway and will be continued in 1966.

6. Salmonella Studies

At Pullman, Washington, studies were continued in cooperation with the Department of Poultry Science, Washington State University, to further define the effects of glow-discharge radiation on Salmonella in dried egg powder. Experiments were designed to better define the lethal treatment for Salmonella, but repeatability of results was not satisfactory. Better control of experimental variables will apparently be required.

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Radiofrequency and Glow-discharge Energy for Insect Control and Treatment of Seed and Plant and Animal Products

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PUBLICATIONS -- STATE EXPERIMENT STATIONS

Radiofrequency and Glow-discharge Energy for Insect Control and Treatment of Seed and Plant and Animal Products

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AREA NO. 12: ELECTRIC EQUIPMENT FOR FARM LABOR REDUCTION

Problem. American agriculture produces about 600 million tons of crop and animal products each year. This is more than five times the weight of the total annual steel production in the United States. Most of these products are handled several times, which means a tremendous task of moving material. Development of equipment to decrease labor of livestock chores has been far less rapid than development of field equipment. For example, the production per man-hour for all crops increased an estimated 525 percent during the last 50 years. This increase is more than twice that for all livestock, 242 percent. Farm output per man-hour rose almost 8 percent from 1964-1965 to 153 percent of the 1957-59 average. The increase for crops as a whole was 2.7 times the gain for livestock. The amount of working time spent on livestock other than horses and mules (estimated to be 3,066 million man-hours per year in 1965) is 38.4 percent of the entire farm labor requirement. Equipment to substitute electric energy or tractor power for hand labor for many farmstead operations is now on the market, but research is needed to provide flexibility of use in existing buildings and to permit automatic control as well as to extend mechanization to other operations. Because livestock chore equipment may be needed 365 days per year, it should pay for itself more quickly than field equipment which may be used only a few days per year. Increased emphasis on automatic materials handling equipment by livestock producers and equipment manufacturers has caused them to obtain advice and counsel of research workers. A continuing aggressive research program is essential to meet the developing needs of this segment of our national economy.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program with engineers working at Beltsville, and cooperatively with state experiment stations, USDA apiarists, and other scientists on basic and applied research. Equipment and control for automatic feeding of livestock and poultry is under development at the Washington and Illinois State Experiment Stations. Work on performance characteristics of upright-silo unloaders and special duty motors is in cooperation with the Minnesota State Experiment Station. Work on equipment for handling bees and honey is in cooperation with the Apiculture Branch, Entomology Research Division, and the Arizona and Wisconsin State Experiment Stations.

The Federal scientific effort devoted to research in this area totals 4.3 scientific man-years; of this number 2.0 are devoted to bee equipment; 1.8 to equipment for livestock and poultry; and 0.5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

The agricultural experiment stations of many of the States have research underway whose major objectives involve the obtaining of information on the uses to be made of electric energy to reduce labor, increase production and improve family living conditions. In the design of these studies provision has been made to develop and investigate new equipment and explore the possibilities for new uses for electricity on the farm and in the home.

Many of the projects are concerned with the varied problems of chore labor mechanization and an expansion of the use of electricity for ventilating, heating, lighting, and cooling under the various production enterprises of today's farming operations. Development and testing of prototype specialized equipment for product collection, processing, packaging, and transport, as well as crop storage, loading and unloading devices, are a part of the overall program of investigations.

Much of the research is conducted cooperatively with the Department.

A total of 7.0 scientist man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Cattle Feeding Equipment

An extensive system has been constructed by the University of Illinois Agricultural Experiment Station (Department of Agricultural Engineering and Dairy Science cooperating) to test and develop the best complete system for optimum mechanization and/or automation of milk production equipment. The initial efforts are directed toward the development of an automatic system for dispensing one or more assembled rations to milk cows for free-choice consumption. The cows are divided into production groups so that individual cow feeding will not be necessary. The ration dispensed to each group is composed of silage (grass or corn) and a premixed concentrate. The proportion of silage and concentrate is varied according to the production level of the group. This system will permit more comprehensive investigation of system design and component functions. Considerable difficulty has been experienced during the past year with malfunctioning components of the automatic controls. More reliable components will be used. The overall purpose of this work is to improve milk production efficiency per man-hour without impairing the performance or health of the milk cow.

The automatic feeding equipment investigation for beef cattle was transferred to that for dairy cows. The requirements for each are similar and a better system was available at the dairy farm. The continuously variable, low-speed, high-torque drive for a high-moisture corn metering auger was tested and proved satisfactory. A publication describing the drive assembly is being prepared.

A pilotless-prime-mover, a new concept for automatic feed transport and distribution is being studied. At this time attention is being devoted to perfection of a guidance system that will permit direction of the powered vehicle on a path without deviation of over 2 inches from the prescribed path. The purpose of the system is to simplify mechanization of extensive cattle feedlots and to improve the means of transporting feed materials from field to storage and from storage to the point of use. A buried wire radiating a low radiofrequency signal will be used to guide the vehicle. Present efforts have been devoted to taking measurements of the RF field about the buried antenna when energized at a range of frequencies to select the frequency best suited to the anticipated soil conditions.

In Minnesota, performance tests of Special Farm Duty Motors have been continued. Design engineers from four motor manufacturing companies have contacted the project leader during the past year to discuss performance requirements. Three manufacturers of silo-unloading equipment have actively sought guidelines for their purchases of motors. Continued advances in improved electrical insulating materials make possible the reduction in size of motor frames. A new classification of motor frames is expected. A new evaluation of performance requirements will be necessary.

B. Hog-Feeding Equipment

Extensive testing of low-power feed mills has been completed. A publication is being prepared describing the results. Mills were tested grinding oats, wheat, and shelled corn. The tests completed suggested that it will be possible to isolate several of the parameters involved in hammer mill grinding to select the most efficient design. The power consumption per ton ground remained essentially constant for varying grinding rates.

C. Apiary Equipment

The experimental electrically heated vibrating uncapping knife for honey combs worked satisfactorily. A thermostat with a 3° F. differential maintained the knife temperature within plus or minus 25° F. with the control set at 175° F.

The electrically heated cappings and bran melter was capable of reclaiming 900 to 1,000 pounds of honey per hour. A two-thermostat control of the finned heaters kept the wax cake liquefied without damaging the honey when the unit was idled overnight.

A blast by a high velocity air stream is very effective for removal of bees from supers and combs. A major obstacle to greater use of an air blast to remove bees is the volume of air required and the size of the fan, blower, or compressor required to supply the air.

Molded plastic bee hives with foam insulation appear to be satisfactory to provide better hive insulation. In the initial test in a cold climate the bees became active before the outside temperature was warm enough for flight. The optimum value of insulation must be determined. It is probable that insulated hive bodies will be an effective means of reducing heat-stress upon bees in extreme temperatures.

A general-purpose vehicle for aiding in hive manipulation and providing a source of power in the bee yard is being developed. It will be of primary aid to those producers using two-queen colonies.

Results on the use of plastic combs by bees for brood and honey storage have been inconclusive. Very soft vinyl plastic combs were not acceptable to bees; however, the development of an acceptable plastic comb will be continued. A soft plastic comb would permit extraction of honey by squeezing, a method which would greatly improve the efficiency of honey processing.

Two groups of 10 hives were alternately cooled and used as a check to determine effect of cooling on honey production. Although limited tests the previous year indicated increased honey production in the cooled hives, no significant improvement was obtained in the 1965 study.

D. Poultry Feeding Equipment

The medium-pressure pneumatic feed conveyor with the simple, low-cost auger feed injector has continued to perform satisfactorily. Units are being made commercially. Numerous inquiries have been received from individuals and manufacturing companies for information on this system of feed conveying. A Farmers' Bulletin has been prepared describing the construction and operation of the system. At Beltsville, the digital time-of-day egg recorder designed and installed last year has been used with low-pressure (2 grams) switches in 813 cages. In a 55-day test the system was 93 percent accurate in recording time of egg lay.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Cattle Feeding Equipment

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Apiary Equipment

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AREA NO. 13: ELECTRIC AND SOLAR EQUIPMENT FOR ENVIRONMENTAL CONTROL

Problem. Research has shown that temperature, light, space, and other environmental factors affect the growth, health, fertility, production, and feed consumption of farm animals. Thus, savings in feed, reduced losses from disease and exposure, and decreased costs of production may justify many environmental improvements. Special controlled environments are necessary for the proper conditioning of crops like tobacco, sweet potatoes, grain, and peanuts; and are extremely effective in maintaining the quality of stored fruits and vegetables and in cooling milk. Current scientific and economic developments indicate that production of vegetables and flowers in the future may require complete control of soil, light, and atmospheric conditions. Engineering problems associated with the application of light to plants have increased in recent years with the need for growth rooms for research and commercial use of light for growing crops. Conditioning and safe storage of high-moisture grain are major problems for a great many farmers. Use of solar heat to aid in drying offers potential economy in this operation. The lack of available electric energy in remote areas of a farm has limited the use of electric devices. Conversion of solar to electric energy at the site for adapting new and more efficient thermoelectric devices to farm application may eventually eliminate this energy shortage.

USDA AND COOPERATIVE PROGRAM

A program at Beltsville has been established whereby engineers from the Agricultural Engineering Division cooperate with Crops Division scientists on basic studies of light and thermal environment and their relation to plants in growth chambers. A basic and applied program of solar energy collection and storage for grain drying is underway in Kansas, in cooperation with Kansas State University. Research on equipment for basic and applied studies involving light and thermal environment for poultry is underway at Beltsville in cooperation with the Poultry Branch, Animal Husbandry Research Division. Basic and applied studies on the use of heat pumps to modify thermal environment for hog production is conducted at Holland, Virginia, in cooperation with the Virginia Agricultural Experiment Station.

The influence of electric equipment and environment on health and disease is being studied in USDA laboratories at Athens, Georgia. Equipment for the application of carbon dioxide to plants is under development at Beltsville and at Kansas State University in cooperation with the Departments of Agricultural Engineering, Horticulture and Physics. Studies on the performance of milk handling equipment are underway at Beltsville in cooperation with the Animal Husbandry Research Division and the Eastern Utilization Laboratory. Performance characteristics are being determined for turf soil heating with electric cable at Purdue University in cooperation with the Departments of Agricultural Engineering and Agronomy of the Purdue

Station; also at Beltsville in cooperation with the Crops Research Division; and at St. Paul, Minnesota, in cooperation with the Departments of Horticulture and Agricultural Engineering. Performance characteristics of equipment are being studied for maintaining enviroment for conditioning potatoes for processing. This work is in cooperation with the Departments of Agricultural and Chemical Engineering, Horticulture and Plant Pathology of the University of Minnesota and the Market Quality Research Division and the Transportation and Facilities Research Division, ARS, East Grand Forks.

The Federal scientific effort devoted to research in this area totals 4.7 scientific man-years; of this number 1.8 are devoted to plant environment equipment; 0.3 to solar equipment; 1.6 to poultry environment equipment; 0.2 to swine environment equipment; 0.3 to thermoelectric equipment; and 0.5 to program leadership.

PROGRAM OF STATE EXPERIMENT STATIONS

The State agricultural experiment stations are engaged in extensive basic and applied research to extend the advantages of controlled environment to all phases of agriculture in order to obtain maximum economic growth, production, product preservation, and product quality. Studies of the possibilities for use of solar energy as well as electric energy to achieve the broad scale objectives are a part of the total program. Among the several investigations involved in these programs are determination of the effects that heat, light, space, and other factors have on farm animals; soil, light and atmospheric conditions on plants; and temperature, humidity and gases on stored products. Special attention is being given to development of means for collection, storage and use of solar energy for structural heating and crop conditioning.

A great portion of this research is cooperative with the Department.

A total of 3.5 man-years is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Equipment for Poultry Environmental Studies

At Beltsville, in cooperation with Poultry Research Branch, the fourth year of a 5-year genetic selection of laying stock responsive to less than a 24-hour day cycle was completed in recently developed environmental facilities.

Percent hen-day egg production was 3 percent above the randombred control for the F3 generation of White Leghorns maintained under 18-hour "short-days". This is somewhat less than the 5 percent difference noted in the previous generation. Egg production of the 24-hour population continued to increase to a level of 82.8 percent, 6.6 percent above the control during the past year. The 18-hour population continued to mature approximately one week later than the 24-hour population. Differences in other economic trait were small. An electronic data recording system has been developed for use

in both houses (18-hour and 24-hour) during the past year. This system is designed to record the time of lay of each egg in an attempt to obtain complete information on the ovulatory sequences of the birds under both environments. This information is punched directly on an 8-channel tape (IBM format) for analysis.

Work was completed on egg sensor mechanisms used with the recording system. With birds in individual cages, a precision snap-action switch with low (2 gram) actuation design resulted in 93 percent accuracy in a 55-day test on 813 cages.

Nine Air Velocity-Heat Tolerance Tests were conducted during this reporting period. Each test involved 12 broilers held at various constant air velocities and subjected to a few hours of heat stress. When air temperatures did not exceed 105° F., heat stress was alleviated by higher air velocities, i.e., the rates of increase and the maximum values of body temperature and respiration rate were less at the higher than at the lower air velocities. More feed and less water were consumed at the higher than at the lower air velocities, but body weights were not affected. When air temperatures were increased above 105° F., the higher air velocities appeared to increase heat stress, i.e., the body temperatures (and in some cases the respiratory rates) increased more rapidly, and the survival times were less at the higher than at the lower air velocities. Heart rates in heat stress were not affected by air velocity, but at moderate air temperatures the rates were greater at the higher than at the lower air velocities.

B. Equipment for Swine Environmental Studies

The research on buildings and equipment for efficient swine production, including the utilization of heat pumps, has been continued in cooperation with the Virginia Agricultural Experiment Station. Two tests were conducted during the past year--one a summer test and the other a winter test. For both tests, temperature extremes in the closed building were controlled by operation of the heat pumps instead of maintaining a constant temperature of 65° F. Two fans were used to provide ventilation at a maximum rate of about 10,000 c.f.m. (About 100 c.f.m. per animal).

During the summer test, it was found that cooling by both heat pumps was required to maintain room temperature below 85° F. with 98 animals in the closed building when outside air temperature was above 85° F. and ventilation fans were not operating. Results on average daily gain and feed conversion with 9, 11, 13, and 16 animals per pen on each floor type closely paralleled data for previous tests. Fully slotted, 1/2-slotted, and 1/4-slotted floors were used in the test. On the other floors, the degree of cleanliness was relative to the percent of slotted area in the respective pen.

For the winter test, the fully slotted floor in semi-controlled environment was converted to 1/2-slotted thus making floors in both the closed and 1/2-open buildings the same. Again, animals at densities of 9, 11, 13, and 16

per pen were placed on each floor type. With 98 animals it was necessary to furnish a very limited amount of supplemental heat to maintain temperature above 55° F. Average daily gain and feed conversion data were similar to that obtained for previous tests. It was found that 16 hogs could be raised in the same size pen as 9 with a slight decrease in gain per animal which might not be significant. Pens with 1/2-slotted floors in the closed building remained cleaner during the test than others with 1/4 of the floor slotted or in pens in the half-open building.

C. Milk Cooling Equipment on Farms

Investigations at Beltsville, Maryland, in cooperation with Dairy Research Branch, were continued to determine the effect on raw milk quality of differing rates of cooling in mechanically refrigerated farm bulk tanks. A system was devised wherein milk of differing levels of microbial contamination can be studied under exactly comparable tank cooling conditions. Studies have been initiated to evaluate the effects of varying cooling rates on the normal raw milk supply from the farm, both alone and with the addition of microbial contaminants having specific relation to food deterioration or public health. Preliminary results indicate that, whereas considerable relaxation of current cooling requirements might be adequate for maintenance of quality in the average grade A raw milk supply, it would not prevent an undesirable population increase resulting from the outgrowth of a massive psychrophilic contamination. The multiplication of Staphylococcus aurous, however, is adequately inhibited at a cooling rate as slow as that which required 3 hours to cool the first milking in the tank to 50° F.

D. Plant and Product Environmental Equipment

1. Carbon Dioxide Fertilization

At Beltsville, studies were conducted on a preliminary basis using new equipment and controls to develop a sound cultural practice for growing various types of plants in a completely controlled environment with CO_2 enrichment. Seeds of several annual flowers were grown from germination to the flowering stage in the greenhouse with supplemental light treatments and in controlled artificial conditions. These conditions consisted of normal temperature (65°-75° F.) and humidity (50-70%) with 2200-2400 ft.-c. of fluorescent and incandescent light for 16 hours of each day. One chamber had uncontrolled CO_2 at about 400 ppm (near atmospheric) while the other was controlled at approximately 1000 ppm. Results of a typical test of growth for a 2-week period are shown on following table. In all instances, the growth in the controlled chambers was much faster and for most plants the flowering was earlier.

Typical Experiment:

Environment	Weight of seedling 2 weeks after start of treatment			
	Petunia Pink Cascade	Ageratum Blue Blazer	Marigold Double Eagle	Snapdragon White Rocket
Greenhouse - 65° Night Temperature	mg	mg	mg	mg
1. 8-hr. day - 16-hr. dark	15	15	203	12
2. Natural days (ND) Feb.	14	13	254	10
3. ND + continuous incandescent (80 ft.-c.)	18	16	206	13
4. ND + continuous fluorescent (250 ft.-c.)	65	42	800	43
Growth Room - 65° Night Temperature				
5. 16-hr. day - 400 ppm CO_2	600	500	4600	358
6. 2200-2400 ft.-c. fluor. & incand. light - 1000 ppm CO_2 av.	3100	1300	12600	900
Ratio: Treatment 6 ÷ treatment 1	206	86	60	75

Plant seeded - 1/28/66

Light treatments - 2/4/66 - 2/18/66

Geraniums grown from seed that normally flower in 18 weeks were flowering in 8 weeks. Petunias normally take 8 weeks or longer, but some with CO_2 fertilization flowered in 35 days.

In Kansas, a system for misting carbonated water has been designed and installed. The controls will provide adjustment of misting cycles over a range of 2 seconds up to continuous application. A control sensitive to sunlight intensity is also part of the system.

2. Plant Growth Lighting, Radiation, and Instrumentation

At Beltsville, the angle transducer has been incorporated to use 10 plant movement sensors through a timed stepping switch to a single-point recorder which records each point for 1 minute out of 10.

Preliminary studies were conducted to develop and test a new technique for greenhouse cooling. In this study preconditioned air was passed between two layers of greenhouse covering to determine how much of the radiant energy can be removed before it enters the greenhouse. Tests were conducted on various materials to determine their ability to pass visible light and their capacity to remove infrared radiation. Solar radiation was simulated by using reflector incandescent lamps. Single and double layer tests were conducted with conditioned air passing between the double layers. Radiation between 1/4 and 2 micron wavelength was measured and preliminary tests indicate that a significant part of the radiant energy of incandescent lamps can be removed while reducing the light only 10-20 percent.

Assistance was given the Crops Research Division in preparing the Bulletin and in designing and constructing the planters, for the publication "Indoor Gardening for Decorative Plants".

3. Electric Equipment for Soil Warming for Plant Growth

Investigations concerning evaluations of electric systems for soil warming were continued in Indiana, Minnesota, and Maryland. The objective of the research was to determine the requirements for installation and management of electric soil warming systems which will maintain suitable turf conditions for activities in critical-use areas during cold weather. Turf heating involves adding heat to the rootzone of turfgrass plants to keep the soil from freezing, keep the turf greener, promote new rootgrowth and blade extension, and help melt snow.

Based on this research program, specifications have been prepared for installing electric heating cables in the turf of the new Civic Center Busch Memorial Stadium at St. Louis and in the Air Force Academy Stadium at Colorado Springs.

The research program showed that the particular design for any installation will depend on the extent of and use for each turf area, the climatic location, the availability of electric energy and the grass species used. Both polyvinyl-chloride insulated nylon-jacketed cables and mineral-insulated copper-clad cables performed satisfactorily. Dense turf with medium thatch was approximately equal to a plastic cover in reducing heat loss.

The capacity of heating cable output/unit area necessary was shown to depend on the weather conditions at a particular location and the condition desired for the turf area. At Lafayette, Indiana, power densities of about 10 watts per square foot sustained Kentucky bluegrass in an active, but not vigorous,

growth state throughout the winter. A density of about 5 watts per square foot was suitable to sustain a green, thawed Kentucky bluegrass turf. No advantage in growth appeared to result from applying heat at low rates for long periods of time when compared with high rates for short periods of time. Results were directly related to total energy added. Less temperature variation occurred when the heat was applied while the air was coldest and the incoming solar radiation minimum. Ryegrass, overseeded December 1, 1964, was 3 inches high by December 30 on heated soil covered by plastic, while unheated soil also covered by plastic, repeatedly heaved and thawed, and seed did not germinate. Existing bluegrass plants were overstimulated when temperatures above 50° F. were maintained at 1-inch depth. These plants were injured by frost during sudden severe cold weather.

Experimentation to study the potential use of electric heating cables under ornamental shrubs was continued cooperatively with the Purdue Department of Horticulture. The objective is to eliminate winterkill due to desiccation and thereby extend the growing period for certain temperature-critical evergreens.

Preliminary studies indicated that the need of supplemental heat for turf was marginal in climates similar to the Beltsville area.

Preliminary results in Minnesota indicate that a conditioning period (gradual reduction in heat) is required prior to removing heat from turfed areas during the cold season. The most severe treatment was heating for 5 weeks after transplanting and abruptly discontinuing heat. Sod with no conditioning period exhibited the poorest color, knitting, root development, and rhizome activity of all treatments. Continuous heat resulted in the maintenance of green color and active root and rhizome development. These are preliminary results and the experiment will require continuing evaluation.

4. Environmental Equipment for Potato Conditioning

In Minnesota, cooperative research is underway to develop equipment for storing and conditioning potatoes so they will be available for processing as much of the year as possible. An experimental refrigeration system has been developed that will store potatoes for up to 9 months without need for defrosting thereby eliminating undesirable conditions due to defrost cycles.

The new system includes an oversize evaporator that operates with only a small difference between air and refrigerant temperatures. This eliminates frost accumulation on the coils, a condition which seriously impairs refrigeration efficiency, especially at the high humidity desired for potato storage. Defrosting cycles, an automatic feature of many conventional refrigeration systems, adds heat to the room or may reduce humidity to a level where an auxiliary humidifier is needed.

The ARS-Minnesota experimental refrigeration system held six potato varieties within 1-1/2 degrees of 40 degrees F.--a high level of precision--

at relative humidities of 85 to 95 percent, for up to 9 months. After a 4-week conditioning period at 65 degrees F. to burn up sugars that would otherwise give the potato flakes a scorched taste, Bounty, Irish-Cobbler, Kennebec, Norgold, Red Pontiac, and Snowflake potatoes gave acceptable instant flakes. Potatoes processed directly from 50-degree storage in other tests, consistently gave more white flakes.

E. Solar Equipment

The solar supplemented heat pump previously reported on is being dismantled, and discontinuance of the project is under discussion.

Plastic collapsible solar air heaters for drying grain are under development and are being tested for the third year. A standard 4-mil clear polyethylene film has weathered well, but some physical breakdown has appeared at certain stress points. Use of a new sun-resistant polyethylene film is being investigated.

The present collapsible plastic solar air heaters provided supplemental heating of air during 1965 fall grain drying tests. Solar energy conversion efficiency was comparable with the previous 2 years' records. Sorghum grain was dried from 26 to 28 percent moisture content to 13 percent or less. Weather conditions were not favorable for natural air drying of sorgnum grain at this high moisture content.

A project is underway at the Atomic Energy Center, Lahore, West Pakistan, using PL 480 funds on the "Development of solar powered equipment for operating a small irrigation pump". During the first year a parabolic mirror collector was constructed as well as a prototype water preheater. A small-scale boiler was also constructed and used to obtain design data for construction of the full-scale boiler.

F. Thermoelectric equipment

In Kansas, analysis of a thermoelectric heating/cooling system using water on both sides of the heat transfer device, has been developed using the IBM 1620 and 1410 computers. An arrangement of dimensionless terms has been determined so that the important variables of input water temperatures, water flow rates and electric energy input can be correlated with cooling and heating rates. Additional computer work is being carried out which will lead to the mathematical combinations of the dimensionless equations involved.

PUBLICATIONS -- STATE EXPERIMENT STATIONS

Equipment for Swine Environmental Studies

Bell, E. S., Marshall, McNeil, Thomas, H. R., Stanley, J. M. 1965. Temperature-controlled swine housing: weaning to market. Transactions of ASAE. 8(4):545-547, 557.

Electric Equipment for Soil Warming for Plant Growth

Daniel, W. H. and Barrett, J. R., Jr. 1966. Electricity warms soils for sport turf. Weeds, Trees and Turf. 5(2):14-16. February.

Daniel, W. H. and Barrett, J. R., Jr. 1966. Soil warming and turf use - 3rd Report. Proceedings Midwest Regional Turf Conference. March.

AREA NO. 14: FARM ELECTRIC SERVICE AND INSTRUMENTATION

Problem. Farms east of the 100th meridian used twice as much electricity in 1959 as they did in 1950 and three times as much as they used in 1945. Increased use has forced many farmers to rewire or partially rewire their farmsteads at considerable cost. Overloading of installed wiring results in poor equipment performance, energy losses in the wiring, and creates a fire hazard. More economical means of providing adequate wiring are needed.

Transformers burn out or must be replaced due to overloading. There has been no good method of predicting when a transformer should be replaced and many power suppliers are faced with the problem of finding a simple, effective one. These problems are expected to become increasingly acute as farmers install additional electrical equipment such as house heating units, air conditioning, milk coolers, motors for feed processing and distribution, and irrigation pumps.

The rapidly increasing demand of Midwestern farmers for large motors is becoming of concern to farm power suppliers. This increase in demand is attributable to the shift from ear corn to shelled corn harvest. Shelled corn is often harvested at high moisture contents and should be dried about as fast as it is harvested.

Today's technology in farming, as well as research, requires accurate instruments for measuring or monitoring processes such as grain and forage drying and plant and animal environment. Current agricultural research is especially dependent upon accurate instrumentation; some problems require completely new kinds of instruments. Studies are necessary to determine the accuracy and practicability of instruments for many kinds of agricultural measurements.

USDA AND COOPERATIVE PROGRAM

The Department has a program involving agricultural and electrical engineers to develop an improved method of estimating the maximum electrical demands of farms. This program is in cooperation with the Iowa Experiment Station, the Rural Electrification Administration, and power suppliers in Iowa, Montana, Minnesota, North Dakota, Wisconsin, Kentucky, and Alabama. Data on energy consumption and electric equipment used on farmsteads are analyzed to predict electric demands by farms situated under similar conditions. Variations in electric equipment due to different crops, farming enterprises, and weather require that studies also be made in other areas. Data obtained in cooperation with members of the Farm Wiring Committee of the American Society of Agricultural Engineers are analyzed in demand studies and in developing and substantiating changes to the National Electrical Code.

At Beltsville, a program is underway to develop and provide accurate, practical and sometimes complex instrumentation for specific program needs.

Federal scientific effort devoted to research in this area totals 2.3 scientific man-years. Of this number 1.0 is devoted to energy distribution and farm electric demand; 1.0 to instrumentation; and 0.3 to program leadership.

PROGRAM OF STATE AGRICULTURAL EXPERIMENT STATIONS

The agricultural experiment stations of a few of the States have research investigations in progress studying the electric demands of farms and the major appliances used on farms in order to evaluate the effects of these demands on farmstead distribution systems. Exploration is also underway on the possibility of developing a safe distribution system for the farmstead using voltages which are higher than those currently allowed under the National Electrical Code.

Many of the studies are cooperative with the Department.

A total of 1.5 scientific man-years effort is devoted to this work.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Energy Distribution and Demand

The 1965 National Electrical Code includes two new sections on demand factors to be used in computing the required sizes of conductors and feeders for farms and farm buildings. In Iowa, these new code sections were drafted and data analyzed to substantiate them. Cooperating were the Farm Wiring Committee of the American Society of Agricultural Engineers, the Edison Electric Institute, the National Rural Electric Cooperative Association, and 113 power suppliers. The new code sections also will be published in the 1966 Agricultural Engineers Yearbook as an ASAE Recommendation. The objectives of this activity have been completed, and no further work is planned.

Estimates of maximum demand are required for sizing farm transformers and secondary services. In cooperation with the Rural Electrification Administration and power suppliers, procedures are being developed to decrease the cost and increase the accuracy of demand estimates. The estimation procedures developed thus far are for 30-minute demands which are useful primarily in preventing thermal overloading of transformers. Of perhaps equal importance to the quality of the electric service received by the farmers is the sizing of transformers and services to hold voltage drop within acceptable limits. Estimates of short-interval demands are required for this purpose. Two recording demand meters were modified to 1.825-minute demand intervals to obtain information on the short-time demands of farms. These meters were operated in series with 15-minute demand meters for 2-week periods on 14 farms. The highest 1.825-minute demand of each of the 14 farms averaged 138 percent of the highest 15-minute demand. The information obtained from this limited study will be used in planning further work.

One of the methods of serving large motors on single-phase lines is to use phase converters and three-phase motors. A new type of phase converter, the rotating transformer, is now being offered for sale. This type of converter has the capability of serving several motors at one time. Tests to determine the load and performance characteristics of motors operated on a rotating-transformer converter were started in cooperation with the Agricultural Engineering Department of Iowa State University and the Iowa Association of Electric Cooperatives. Preliminary tests of the performance of three-phase motors operating on a balanced three-phase power source and on a rotary-phase converter have been conducted. Measurements of the temperature rises in the motors are planned in order to determine any reduced rating necessary in loading motors operating on rotary-phase converters.

The high cost of farmstead wiring is slowing the additional uses of electric energy on farms. At the request of the Member Service Coordinator of REA, the cost of farm wiring is being investigated to determine if there are areas in which publicly sponsored research may contribute to lower wiring costs. The approximate hours of labor and the materials required for conventional meter loops have been determined. Labor and materials costs for current transformer metering, feeders from the meter to farm buildings, and building service entrances will be investigated before recommending areas for further study.

B. Research Instrumentation

Spectral distribution measurements of lamps used in insect traps for 3 years (5 months' use per year) showed little or no change. This indicates that lamps may be used in field equipment for 2 years assuming 8 months' continuous use per year. Similar studies were initiated for lamp sources used in plant growth chambers.

A meter for measurement of ultraviolet (UV) irradiance was developed. Eighteen meters were constructed for use of research engineers in determining actual light trap lamp UV irradiance. The meter makes possible standard measurements by research investigators of lamp irradiance and comparison evaluation of trap electrical performance. The meters were calibrated in the spectral laboratory.

In cooperation with the Poultry Branch, a digital event recorder for time of lay was developed and installed in the poultry facility at Beltsville. Preliminary 55-day test data indicated 93 percent accuracy when used with 813 caged layers. Record information is printed for local readout and punched on paper tape for computer analysis. With hens in modified individual sloping floor cages, each egg rolls to the extended front of the cage floor and mechanically closes an electrical switch. Each switch is connected to the recorder by two wires. One wire is common to all switches. Once an hour the recorder scans the switches in sequence and punches on paper tape the coded numbers of the electrically closed switches. After the first egg in each cage is recorded each day, no additional records for that cage will

be entered in the recorder until the eggs are removed and the recorder reset. A digital clock provides exact time of scanning and punched time data. In addition to the punched tape, the recorder can print a numerical record on adding machine tape. The recorder can be activated manually to determine either the complete list of switches closed since the last egg gathering, or the stored information on switches closed. One switching or scanning unit is used for each 500 birds. Each scanning unit has six wires (telephone-type cable) to the master recorder and requires separate 120-volt power. In the event of power failure, a battery operates the clock to maintain time for about 3 hours. Upon resumption of power, regular scanning is automatically resumed with only loss of exact event-times during the outage.

PUBLICATIONS -- USDA AND COOPERATIVE PROGRAMS

Energy Distribution and Demand

Carpenter, T. G., Charity, L. F., and Altman, L. B. 1965. Farmstead wiring for large and scattered loads. Transactions of ASAE. 8(2):157-160.

Research Instrumentation

Junnila, W. A. and Flikke, A. M. 1966. Instruments and controls in livestock and poultry production. IEEE Transactions. Vol. IECI-13(1):27-30.

PUBLICATIONS -- STATE EXPERIMENT STATIONS

Energy Distribution and Demand

Charity, L. F. and Altman, L. B. 1965. Design of electrically heated concrete slabs. Transactions of ASAE. 8(3):409, 410, 416.

Line Project Check List -- Reporting Year April 1, 1965 to March 31, 1966*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Area & Sub-heading
AE a1	Weed, insect pest, & plant disease control machinery Program leadership	Beltsville, Md.		
AE a1-1 (Rev.#2)	Equipment for application of pesticides, defoliants, fertilizers and seeds from agricultural aircraft.	Wooster, Ohio Forest Grove,Ore.	Yes	3-H-1
AE a1-4	Develop equipment & techniques for application of insecticides & fungicides to crops by ground machines.	Wooster, Ohio Forest Grove, Ore.	Yes	3-F-1
AE a1-6 (Rev.#2)	Aerial spray equipment for forest insect control.	Beltsville, Md.	Yes	3-I-1
AE a1-11 (Rev.)	Equipment for the application of chemicals to the soil for control of soil pests.	Wooster, Ohio	Yes	3-B-1
AE a1-12 (Rev.)	Investigations of equipment & techniques for mechanical & chemical control of weeds in crops.	Columbia, Mo. Ames, Iowa Stoneville, Miss.	Yes	3-D-1 3-E-4
AE a1-15 (sup.part AEc5-2)	Equipment for the above-ground application of agricultural chemicals in cotton.	Auburn, Ala. Shafter, Calif. Lubbock, Tex. Stoneville, Miss.	Yes	3-E-1
AE a1-16 (sup.part AE c5-2)	Equipment for soil incorporation of chemicals for cotton pest control.	Stoneville, Miss. Shafter, Calif.	Yes	3-E-2
AE a1-17	New mechanical and/or physical methods for insect control on grain crops.	Tifton, Ga.	Yes	3-C-3
AE a1-18	Developing equipment for practical control of insects on grain crops grown in the Southeast	Tifton, Ga.	Yes	3-C-2
AE a1-19	Detecting and measuring spray deposits on corn ears and silks	Tifton, Ga.	No	
AE a1-20	Mechanical methods of destroying fallen cotton squares.	State College, Miss.	Yes	3-E-3
AE a1-21	The development and evaluation of equipment and techniques for broadcast applications of granular pesticides with air blast machines.	Wooster, Ohio	No	
AE a1-22	Evaluation of devices for distribution and metering of pre-emergence herbicides on the soil and mixed with the soil in the surface layer.	Ames, Iowa and Columbia, Mo	Yes	3-D-2
AE a1-23 (sup. AEa1-3)	The development and evaluation of equipment for control of corn insects in the Midwest.	Wooster Ohio Ames, Iowa	Yes	3-C-1
AEa1-24(C)	Equipment for application of agricultural materials from fixed-wing aircraft.**	State College, Miss.	Yes	3-H-2
AE a1-25	Pesticide equipment and techniques for control of of fruit, vegetable, and field crop insects and diseases. **	Yakima, Wash.	Yes	3-G-1
AE-0-0-2 (DOD)	Equipment and techniques for applying herbicides to vegetation in Puerto Rico and Texas	Mayaguez, P.R. College Sta.,Tex.	Yes	3-J-1
A10-AE-5 (PL-480)	Application of air jets with a vortex to improve penetration of air-borne insecticide sprays into dense foliage of citrus trees.	Rehovot, Israel	Yes	3-K-1
Charter	Physics of Fine Particles, Pioneering Research Laboratory	Wooster, Ohio	Yes	3-A-1
AE a2	Planting & fertilizing equipment and practices Program leadership	Beltsville, Md.		
AE a2-4 (Rev.)	Equipment for applying liquid fertilizer. ***	Beltsville, Md. E.Lansing, Mich.	No	
AE a2-5 (Rev.)	Laboratory studies of the performance characteristics of seeding and fertilizer dispensing devices and equipment. ***	Beltsville, Md.	No	

* Reporting year for all projects concerned with cotton--July 1, 1965 to June 30, 1966.
** Initiated during reporting year.
*** Discontinued during reporting year.

Line Project Check List -- Reporting Year April 1, 1965 to March 31, 1966*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Area & Sub-heading
AE a2-8 (sup.AEa2-1 rev.)	Equipment and practices for pasture and hay land establishment and maintenance	Beltsville, Md. Bushland, Tex. Athens, Ga.	Yes	2-B-1
AE a2-9	Development of equipment and techniques for cotton planting	St.Coll.& Stoneville, Miss. Shafter, Calif. Auburn, Ala. Lubbock, Tex.	Yes	2-C-2
AEa2-10(C)	Design and development of range seeding equipment for use with brush eradication equipment in the arid Southwest.	Las Cruces, New Mexico	Yes	2-B-2
AE a2-11 (sup.AEa2-2 rev.)	Planting and fertilizing placement machinery for cultivated field crops & vegetable crops.	Ariz.,Fla.,Ga., Md., Mich., Nev., Tex.,Va., Wash.	Yes	2-A-1 2-D-1 2-C-3
AE-00-1	Equipment and methods for decontamination of agricultural lands affected by radioactive fallout.	Beltsville, Md.	Yes	2-E-1
AE a3	Tillage machinery investigations Program leadership	Beltsville, Md.		
AE a3-1 (rev.)	Soil dynamics as a factor in tillage tool design	Auburn, Ala. Ames, Ia.	Yes	1-C-1
AE a3-2 (rev.#2)	Basic studies of soil-working tools.	Auburn, Ala.	Yes	1-D-1
AE a3-3 (rev.)	Soil compaction by machinery.	Auburn, Ala.	Yes	1-B-1
AE a3-4 (rev.)	Design and use of deep tillage implements.	Auburn, Ala.	No	
AE a3-5 (rev.)	Effect of design factors on traction and transport equipment performance.	Auburn, Ala.	Yes	1-A-1
AE a3-6 (rev.#1)	Development of tillage machinery that will reduce soil erosion and runoff.	Ames, Iowa	Yes	1-E-1
AE a3-7 (rev.)	Measurement and characterization of physical properties of soil as related to tillage implements and tractive effort.	Auburn, Ala.	Yes	1-C-1
AE a3-8 (rev.)	Mathematical relationships between forces and deformation in soil.	Auburn, Ala.	No.	
AE a3-11	Equipment for transferring soil layers and improving surface soil characteristics.	Stoneville,Miss.	Yes	1-B-4
AE a3-12 (sup.AEa3-1,-2,&-4)	Basic studies of soil-working tools	Auburn, Ala.	Yes	1-D-1
AE a3-13 (sup.AEa3-3 &-5)	Basic studies of traction and transport devices	Auburn, Ala.	Yes	1-A-1 1-B-1
AE a3-14 (sup.AEa3-7 &-8)	Characterization of dynamic properties and physical conditions of soil in relation to tillage and traction	Auburn, Ala.	Yes	1-C-1
E15-AE-1 (PL-480)	Development of methods and equipment for breaking up cohesive clay soils into small clod sizes up to a deep depth.	Bologna, Italy	Yes	1-F-1
A10-AE-3 (PL-480)	Soil structure - tillage interactions	Rehovot, Israel	Yes	1-F-2
A10-AE-4 (PL-480)	Effect of knife angle and velocity on cutting of roots and rhizomes in the soil.	Beit Dagan, Israel	Yes	1-F-3
AE b1	Farm housing Program leadership	Beltsville, Md.		

*Reporting year for all projects concerned with cotton--July 1, 1965 to June 30, 1966.

Line Project Check List -- Reporting Year April 1, 1965 to March 31, 1966*

Work & Line Project Number	Work and Line Project Titles	Work Locations During Past Year	Line Proj. Summary of Progress	Incl. in Area & Sub-heading
AE b1-2 (Rev.#2)	Experimental farmhouses	Beltsville, Md.	No	
AE b1-3	The effect of selected construction and heat distribution means on environment, livability and climatic response in an expansible farmhouse ***	Beltsville, Md.	No	
AE b1-5	Optimum attic fan arrangements for modern rural dwellings	Athens, Ga.	Yes	8-C-1
AE b1-6	Effect of window and floor coverings on thermal environment in modern rural dwellings	Athens, Ga.	Yes	8-A-1
AE b1-7	Effect of window and floor coverings on noise environment in modern rural dwellings	Athens, Ga.	Yes	8-A-2
AE b1-8	Rural dwelling plan development	Beltsville, Md.	Yes	8-A-3, 8-D-1
AE b1-9	Planning guides for housing units for senior citizens	Beltsville, Md.	Yes	8-D-1
AE b1-10	Planning guides for housing units for migratory and seasonal farm workers	Beltsville, Md.	Yes	8-D-2
AE b2	Livestock shelters Program leadership	Beltsville, Md.		
AE b2-1 (Rev. 2)	Determination of environmental design criteria for poultry house design	Beltsville, Md.	Yes	9-D-1
AE b2-2 (Rev)	Environmental factors influencing development, production & health of dairy & beef animals under controlled conditions ***	Columbia, Mo.	Yes	9-A-2
AE b2-7 (Rev)	Livestock shelters for southeast	Tifton, Ga.	Yes	9-C-2
AE b2-8	Evaluation & development of equipment & procedures for reducing chemical hazards associated with the control of livestock insects	Kerrville, Tex.	Yes	9-G
AE b2-9	Evaluation of radiant fluxes from the sky, ground & surroundings & their influence on the radiant environment of livestock	Davis, Calif Columbia, Mo.	Yes	9-F
AE b2-10	Use of models for analyzing farmstead layouts	St. Paul, Minn.	Yes	10-E-1
AE b2-11	Time standards for farmstead work elements	St. Paul, Minn.	Yes	10-E-2
AE b2-12	Principles of planning farmstead layouts to reduce labor required in production of livestock and poultry	Davis, Calif.	Yes	9-A-1
AE b2-13	Development of prototype environmental cabinet for poultry disease research	Athens, Ga.	Yes	9-D-2
AE b2-14	Design and layout criteria for labor-saving structures and related equipment for feeding cattle	Davis, Calif.	No	
AE b2-15	Environmental stress zones as criteria for design of heating, ventilating & air-conditioning equipment for turkey production	St. Paul, Minn.	Yes	9-D-5
AE b2-16	Bioengineering studies relating to environmental factors & physiological responses of swine with emphasis on humidity & high temperatures	Davis, Calif.	Yes	9-C-1, 4,5
AE b2-17	Bioengineering studies of factors affecting the relationship of environment & growth & feed utilization of beef cattle	El Centro, Calif.	Yes	9-B-1
AE b2-18	Development & test of shelters & related equipment for protecting farm animals from hot, dry climates	Davis, & El Centro Calif.	Yes	9-B-1,F
AE b2-19	Measurement of eggshell thickness with radioactive isotopes**	Beltsville, Md.	Yes	9-D-7
AE b2-20	Bioengineering studies relating climatic factors & physiological responses of dairy cattle**	Columbia, Mo.	Yes	9-A-2

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AE b2-21	Buildings and related equipment for sheltering farm animals, principally dairy cattle in the Midwest	Columbia, Mo.	Yes	9-A-2
AE b3	Storages & related equipment for farm products Program leadership	Beltsville, Md.		
AE b3-10 (Rev)	Studies of basic factors in design & operation of silos	Beltsville, Md.	Yes	7-A-1-2
AE b3-11 (Rev)	Development of improved methods, equipment & structures for making, storing & feeding silage in southeast***	Athens, Ga.	No	
AE b3-12	Farm storage of high moisture grain	Ames, Iowa	No	
AE b3-13	Silage and other forage density measurement with radioactive isotopes	Beltsville, Md.	Yes	7-A-1
AE b3-14 (Rev)	Pressures of wheat & soybeans on bin walls, floors and structural members	Ames, Iowa	No	
AE b3-15	Structures and related equipment for control of plant environment	Beltsville, Md.	Yes	7-B-1,2, 3,4,5,6
AE b3-17	Structural design criteria for large tower silos**	Beltsville, Md.	No	
AE b4	Farm building plan exchange & information Program leadership	Beltsville, Md.		
AE b5	Materials & construction methods for farm buildings Program leadership	Beltsville, Md.		
AE b5-5	Development & evaluation of Portland cement-sand sandwich panels***	Beltsville, Md. Blacksburg, Va.	No	
AE b5-6	Incorporation & application of hyperbolic paraboloid (HP) theory to the structural use of sheet materials in farm structure roof design	Beltsville, Md.	Yes	10-C-1
AE b5-7	Evaluation of rotational resistance of nailed joints to be used in farm structures***	Blacksburg, Va.	No	
AE b5-8	Floor deck and slab studies (primarily for rural dwellings)	Beltsville, Md.	Yes	8-B-1
AE b5-9	Influence of housing structures & equipment on airsaculitis & condemnations of broilers***	State College Miss.	Yes	9-D-3,4
AE b5-10	Investigations of the nature and magnitude of wind forces on farm structures	Blacksburg, Va.	Yes	10-A
AE b5-11	Building foundations in expansive clay soils	Starkville, Miss.	No	
AE b5-12	Farm service building plan development	Beltsville, Md.	Yes	10-C-3,7-C,9-A-3,9-B-3,9-C-6 9-D-8
AE b5-13	Prototype low-cost house construction	Charlestown,W.Va.	Yes	8-B-2,8-C-2
AE b5-14	Safety features for rural structures	Beltsville, Md.	Yes	10-B
AE b5-15	Influence of construction, equipment,& management of broiler houses on airsaculitis and condemnations**	State College, Miss	Yes	9-D-3,4
AE b6	Farmstead water supply & wastes disposal Program leadership	Beltsville, Md.		
AE b6-2 (Rev)	Design criteria for livestock farmstead water systems	College Pk. Md.	Yes	10-D-1
AE b6-3	Characteristics of farm animal manures affecting design of disposal facilities	College Pk. Md.	Yes	10-D-3
AE b6-4	Farm animal manure disposal lagoons	College Pk. Md.	Yes	10-D-3
AE b6-5	Pesticide pollution of farmstead water supplies**	Beltsville, Md. Watkinsville, Ga.	Yes	10-D-2
A7-AE-3 (PL 480)	Studies on use of pure strains of algae & mixed algae-protozoa & algae-bacteria cultures in sewage treatment	Baroda, India	Yes	10-D-4

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AEc1	Cotton ginning investigations Program leadership	Beltsville, Md.		
AEc1-14 (Rev)	Measuring elements of fiber quality as affected by ginning & associated operations***	Stoneville, Miss. Mesilla Park, N.M. Clemson, S. C.	Yes	6-F-1
AEc1-15 (Rev)	Moisture contents of cotton for optimum gin house operation***	Stoneville, Miss. Mesilla Park, N.M.	Yes	6-B-1
AEc1-24 (Rev)	Fundamental mechanisms of nep formation in cotton	Mesilla Park, N.M.	Yes	6-F-2
AEc1-28 (Rev)	Reducing the degrading effects of weathering in the field & the action of insects & microorganisms on ginned cotton fiber & seed	Clemson, S. C.	Yes	6-C-2
AEc1-31	Cotton ginning efficiency and cost***	Clemson, S. C.	Yes	6-F-8
AEc1-32	Development of alternative seed cotton cleaning devices & methods based on a thorough evaluation of present equipment***	Stoneville, Miss.	Yes	6-C-1 6-I-2
AEc1-33	Improvement & evaluation of equipment for cleaning lint cotton***	Stoneville, Miss.	Yes	6-G-1
AEc1-34	Improving cotton ginning performance through cotton quality evaluations & their relationships to ginning and associated operations	Mesilla Park, N.M. Clemson, S. C.	Yes	6-F-7
AEc1-35	Improving extra long staple cotton ginning means & methods	Mesilla Park, N.M.	Yes	6-E-2
AEc1-36	Roller gin adjustment for optimum performance	Mesilla Park, N.M.	Yes	6-E-3
AEc1-37	Measurement of raw cotton length for cotton ginning evaluation	Stoneville, Miss. Mesilla Park, N.M.	Yes	6-F-3
AEc1-38	Gin stand research and development	Mesilla Park, N.M. Clemson, S. C.	Yes	6-E-1 6-I-1
AEc1-39	Materials handling & collection at cotton gins	Stoneville, Miss. Mesilla Park, N.M.	Yes	6-A-1 6-D-1 6-J-1
AEc1-40	Effects of production & harvesting methods & practices on cotton ginning & fiber quality	Stoneville, Miss. Mesilla Park, N.M.	Yes	6-F-5 6-F-6
AEc1-41	Cotton bale packaging improvement	Stoneville, Miss.	Yes	6-H-1
AEc1-42	Relationship of temperature, moisture, impact, & tensile stresses during ginning to fiber strength, length distribution, & yarn quality	Stoneville, Miss. Mesilla Park, N.M.	Yes	6-F-4
AEc1-43	Determinations of electrostatic properties of of cotton**	Clemson, S. C.	Yes	6-J-2
AEc2	Long vegetable fiber engineering investigations Program leadership	Beltsville, Md.		
AEc2-2 (Rev)	Improving processes & techniques for cleaning ramie ribbons***	Belle Glade, Fla.	No	
AEc2-7 (Rev)	Development harvesting & farm handling equipment for bamboo***	Belle Glade, Fla.	No	
AEc2-8 (Rev)	Sansevieria harvesting, defibering, & fiber conditioning machinery & methods***	Belle Glade, Fla.	No	
AEc2-9 (Rev)	Development of improved harvesting & processing machinery & methods for the production of kenaf and other jute like fibers***	Belle Glade, Fla.	No	
AEc3	Equipment for harvesting & farm handling of fruits & vegetables Program leadership	Beltsville, Md.		
AEc3-13 (Rev)	Equipment & methods for handling & harvesting Concord grapes***	E. Lansing, Mich.	No	
AEc3-14 (Rev)	The effect of tillage & cultural practices on mechanized potato harvesting***	E. Grand Forks, Minn.	No	
AEc3-21	Mechanical injury of potatoes-evaluation, causes & prevention	E. Grand Forks, Minn.	Yes	4-G-1

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AEc3-24	Equip. & methods for harvesting dates mechanically***	Davis, Calif.	Yes	4-C-7
AEc3-25	Equip. & methods for harvesting & field handling citrus fruit	Lake Alfred,Fla. Davis, Calif.	Yes	4-A-1
AEc3-26	Mechanical aids and harvesting equip. & methods for picking apples for the fresh market	Wenatchee, Wash. E. Lansing, Mich.	Yes	4-C-1
AEc3-27	Mechanized picking of apples & pears for processing outlets.	Wenatchee, Wash. E. Lansing, Mich.	Yes	4-C-2
AEc3-28	Development of equip. & methods for harvesting of apples & pears from trees of different sizes, shapes & planting distances.	Wenatchee, Wash. E. Lansing, Mich.	Yes	4-C-2
AEc3-29	Development of continuous-type self-propelled machine for harvesting cultivated blueberries	E. Lansing, Mich.	Yes	4-C-3
AEc3-30	Equip. & methods for maintaining quality of cherries during mechanical harvesting & handling	E. Lansing, Mich.	Yes	4-C-4
AEc3-31	Methods & equip. for harvesting prunes grown in the Coastal Region of California	Davis, Calif.	Yes	4-C-5
AEc3-32	Bark damage to fruit trees resulting from mechanical shakers	Davis, Calif. Lake Alfred,Fla. E.Lansing, Mich.	Yes	4-C-6
AEc3-33	Development of methods & equip. for multirow harvest of potatoes	E.Gr.Forks,Minn.	Yes	4-G-2
AEc3-34	The development of equip. for application of dust to seed potatoes	E.Gr.Forks,Minn.	Yes	4-G-3
AEc3-35	The development of equip. & methods for harvesting coffee	Honolulu and Kona, Hawaii	Yes	4-C-10
AEc3-36	Equip. & methods for pollination of dates**	Riverside,Calif.	Yes	4-C-8
AEc3-37	Development of improved harvesting procedures & equip. for clingstone peaches**	Davis, Calif.	Yes	4-C-9
AEc4	Farm seed cleaning & handling Program leadership	Beltsville, Md.		
AEc4-4 (Rev)	Seed cleaning research applied to specific problem mixtures	Corvallis, Ore.	Yes	5-A-1
AEc4-8 (Rev)	Development of a centrifugal-pneumatic seed separator	Corvallis,Ore.	Yes	5-A-2
AEc4-13	Development of a high-speed scalper for seed crops	Corvallis, Ore.	Yes	4-E-1
AEc4-14	Development of components for cutting, picking up, threshing, & cleaning field seed crops	Corvallis, Ore.	Yes	4-E-2
AEc5	Equipment for mechanical cotton production Program leadership	Beltsville, Md.		
AEc5-4	Equipment & techniques for crop residue disposal in crop production	Stoneville, Miss.	Yes	2-B-1
AEc5-5	Equipment & methods for optimum seedbed preparation for cotton	Lubbock, Texas Shafter, Calif.	Yes	1-B-2
AEc5-6	Power requirements of cotton production implements	Shafter, Calif.	Yes	1-B-3
AEc5-7	Synthetic mulches for improving cotton stands	Stoneville, Miss. Lubbock, Texas	No	
AEc5-8	Cooperative studies on the effects of production practices on the end use quality of cotton & cottonseed	Stoneville, Miss. Auburn, Ala. Lubbock, Texas	Yes	4-B-1 4-B-5
AEc5-9 (Rev)	Evaluation & development of cotton harvesting machines	Stoneville, Miss. Lubbock, Texas Auburn, Ala.	Yes	4-B-4
AEc5-10	Reduction of moisture added to seed cotton by spindle-type harvesters	Stoneville, Miss. Shafter, Calif.	No	
AEc5-11	Sources of trash in cotton harvesting	Shafter, Calif. Stoneville, Miss.	Yes	4-B-2
AEc5-12	Plant characteristics affecting the performance of mechanical cotton harvesters	Auburn, Ala. Stoneville, Miss.	Yes	4-B-3

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AEc5-13	Field separation of immature cotton bolls from mature cotton	Lubbock, Texas	No	
AEc5-14	Field handling & storage of machine-harvested cotton	Lubbock, Texas	Yes	4-B-6
AEc5-15(C)	Cottonseed germination & quality as affected by harvesting & ginning operations	State College,Miss. Clemson, S. C. College Station,Tex.	Yes	4-B-7
AEc6	Grain harvesting & conditioning Program leadership	Beltsville, Md.		
AEc6-11 (Rev)	Moisture relations in grains as they affect drier design	Ames, Iowa	Yes	5-C-1
AEc6-12 (Rev)	Studies of the drying zone in mechanical grain driers	Ames, Iowa	Yes	5-C-2
AEc6-14 (Rev)	Mechanical damage to corn during harvesting & handling	Ames, Iowa	Yes	5-C-3
AEc6-15 (Rev)	Permissible time for drying grain using unheated air	Ames, Iowa	Yes	5-C-4
AEc7	Specialized crop production & harvesting machinery Program leadership	Beltsville, Md.		
AEc7-8 (Rev)	Development & improvement of peanut diggers & shakers	Tifton, Ga. Holland, Va.	Yes	4-F-3
AEc7-9 (Rev)	Development & improvement of tung harvesters & windrowers for optimum effectiveness & efficiency	Bogalusa, La.	Yes	4-F-2 5-E-1
AEc7-10 (Rev)	Development & improvement of equipment & methods of handling tung fruit to storage on farm & to processing mill	Bogalusa, La.	No	
AEc7-11 (Rev)	Farm processing of tung nuts	Bogalusa, La.	Yes	5-E-2
AEc7-13 (Rev)	Development & improvement of peanut harvesting & field handling equipment	Holland, Va.	Yes	4-F-5
AEc7-14 (Rev)	Development of improved harvesting, hulling & conveying equipment for castor beans & other oilseed crops***	Stillwater,Okla.	No	
AEc7-16	Engineering studies of factors related to harvesting & farm processing Coastal bermudagrass	Tifton, Ga.	Yes	4-D-1 5-D-1
AEc7-17	Mechanical harvesting Burley tobacco	Lexington,Ky.	Yes	4-I-1
AEc7-18	Curing Burley tobacco	Lexington,Ky.	Yes	5-B-1
AEc7-19	Physical properties, forms, & treatments of forage***	Beltsville, Md.	Yes	4-D-2
AEc7-20	Pruning of tung trees for facilitating the use of equipment in production & harvesting	Bogalusa, La.	Yes	4-F-1
AEc7-21	Determine the engineering requirements for artificially conditioning castor beans for effectively hulling & maintenance of quality in storage***	Stillwater,Okla.	No	
AEc7-22(C)	Mechanically removing tops & lead trash from sugarcane	Baton Rouge,La.	Yes	4-H-2
AEc7-23	Gathering & cutting recumbent-type sugarcane from the row	Belle Glade,Fla.	Yes	4-H-1
AEc7-24(C)	Equipment & methods for the farm curing & drying of Virginia-type peanuts	Blacksburg,Va.	Yes	5-F-1
AEc7-25	Equipment & methods for the farm curing & drying of peanuts	Tifton, Ga. Holland, Va.	Yes	5-F-2
AEc7-26(C)	Determination of location, nature, & extent of losses & damage occurring in peanut harvesting & farm handling	Tifton, Ga.	Yes	4-F-4
AEc7-27	Improved forage harvesting & processing methods**	Beltsville, Md.	Yes	4-D-3
S3-AE-2 (PL-480)	Investigations in mechanization of sugarcane	Brazil, S.A.	Yes	4-H-3

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AEd2	Automatic electric controls for farm equipment Program leadership	Beltsville, Md.		
AEd2-1 (Rev)	Development of electric & other labor-saving & honey-conditioning equipment for apiary operation in North Central states	Madison, Wis.	Yes	12-C
AEd2-2 (Rev)	Development of electric & other labor-saving & honey-conditioning equipment for apiary manipulation in S.W.	Tucson, Ariz.	Yes	12-C
AEd2-5 (Rev)	Automatic electric control systems and equipment for livestock production	Urbana, Ill.	Yes	12-A-B-D
AEd2-6	Electric equipment for removing & handling silage from horizontal silos	Pullman, Wash.	No	
AEd3	Electric equipment for environmental modification & control in farm living & production Program leadership	Beltsville, Md.		
AEd3-3 (Rev)	Study of electrical heat pumping devices for agricultural application with solar supplementation for the airconditioning of farm homes and other farm buildings	Manhattan, Kans.	Yes	13-E 13-F
AEd3-7	Electric equipment for efficient hog production (including heat pump for cooling & heating hog houses)	Holland, Va.	Yes	13-B
AEd3-8	Design factors for electrically controlled air flow and ventilation equipment in broiler houses	Athens, Ga.	Yes	13-A
AEd3-9	Relation & control of carbon dioxide & light & their effects on plants in air-supported plastic greenhouses***	Pullman, Wash.		
AEd3-10	Development of electric equipment to provide environmental control for investigations of sub-circadian periodicity in poultry	Beltsville, Md.	Yes	13-A
AEd3-11	Development of design criteria for lighting and other electrical equipment & controls for plant-growth environments	Beltsville, Md.	Yes	13-D-1,2
AEd3-12	Engineering design and development of equipment & controls to modify plant environment by the application of carbonated water to supply supplemental carbon dioxide	Manhattan, Kans.	Yes	13-D-1
AEd4	Application of electromagnetic radiation to plants, animals, & their products & to insects & soils Program leadership	Beltsville, Md.		
AEd4-1 (Rev)	Development of equipment for attracting and/or destroying economic insects with electric energy in North Central states	Lafayette, Ind. Ames, Iowa	Yes	11-A-1,2,5 11-B
AEd4-2 (Rev)	Use of radiofrequency energy for insect control and conditioning of farm products	Lincoln, Nebr.	Yes	11E-1,3
AEd4-3 (Rev)	Development of electrical equipment for attracting and/or destroying economic insects in the S.W. states	College Sta., Tex.	Yes	11-A-3 11-B
AEd4-4 (Rev)	Development of electromagnetic radiation equipment for seed & plant product treatment	Knoxville, Tenn. Pullman, Wash. College Sta., Tex.	Yes	11-E-1,2, 3,4,5,6
AEd4-5 (Rev)	Development of equipment for attracting, repelling and/or destroying economic insects with certain physical stimuli in southeastern states and St. Croix	Blacksburg, Va. Oxford, N.C. Lexington, Ky. St. Croix, V.I.	Yes	11-A-4 11-B 11-C

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AEd4-6	Evaluation & development of equipment & physical methods for control of flies & other livestock pests	Beltsville, Md.	Yes	11-C
AEd4-7	The response and physiological effects of light on the boll weevil	State College, Miss.	Yes	11-A-3
AEd4-8(C)	Insect response to sound stimuli	Blacksburg, Va.	Yes	11-D
AEd4-9(C)	Electric insect traps for control of tobacco insects	Oxford, N.C. Lexington, Ky. Blacksburg, Va. South Carolina Quincy, Fla. St. Croix, V. I.	Yes	11-A-4
AEd4-10	Development of equipment for attracting and/or destroying economic insects with electric energy in the Pacific Coast states	Riverside, Calif. Yakima, Wash.	Yes	11-A-1,6
AEd4-11	Development of equipment, instrumentation, and methods for the use of electromagnetic, sonic, and ultrasonic energy for the control of cotton insects**	Florence, S.C. Blacksburg, Va.	Yes	11-D
AE-ENT-1(C)	Investigation of insect attraction and communication possibilities in the infrared spectral region	Beltsville, Md.	No	
AE-ENT-2(GR)	The influence of electromagnetic energy on green peach aphid, Myzus persicae (Sulzer)**	Lafayette, Ind.	No	
AEd5	Farm electric equipment performance & requirements & farm electric energy distribution Program Leadership	Beltsville, Md.		
AEd5-1 (Rev)	Determination of electric demand characteristics of farm equipment	Ames, Iowa	Yes	14-A
AEd5-3	Electric milk cooling & handling equipment performance requirements	Beltsville, Md.	Yes	13-C
AEd5-4 (Rev)	Performance tests of unloaders for vertical silos	St. Paul, Minn.	Yes	12-A
AEd5-6	Evaluation of electric systems for soil warming	Lafayette, Ind.	Yes	13-D-3
AEd5-7	Development of requirements & electric equipment for conditioning potatoes for processing	E. Gr. Forks, Minn. St. Paul, Minn.	Yes	13-D-4
AEd6	Development of technical instruments & measurement techniques for farm production & related electrification research Program Leadership	Beltsville, Md.		
AEd6-2 (Rev)	Evaluation of lamps producing ultraviolet and visible electromagnetic irradiance (0.2 to 1.0 micron wavelength)	Beltsville, Md.	Yes	14-B
A17-AE-1 (PL 480)	Development of solar powered equipment for operating a small irrigation pump	Lahore, Pakistan	Yes	13-E

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